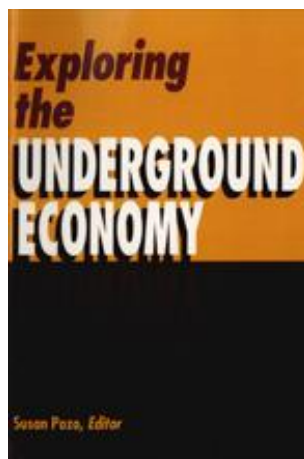


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# Overseas Holdings of U.S. Currency and the Underground Economy

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# Overseas Holdings of U.S. Currency and the Underground Economy

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Many public policy decisions require analytical and empirical knowledge concerning the size, growth, causes, and consequences of the “underground economy.” This paper seeks to clarify the meaning of underground activity, updates various discrepancies and fiscal estimates of its size and growth, and examines the empirical implications of new evidence concerning the growing use of U.S. currency throughout the world for indirect monetary estimates of the underground economy in the United States.

The popular term “underground economy” is inexact, covering a wide range of economic activities that encompass the production and distribution of illegal goods and services, as well as legal activities whose concealment from or misrepresentation to governmental authorities involves tax evasion or benefit fraud. Given the diversity of hidden activities, it is necessary to develop a taxonomy of “underground economies” that identifies specific types of underground behaviors and suggests appropriate methods for estimating their size and their unique economic implications. The general penchant to hide underground economic activities often precludes direct observation of their occurrence, necessitating the use of indirect measures that seek to uncover the footprints of hidden activities left behind in the sands of observable economic indicators. Currency, being an anonymous medium of exchange, is regarded as the preferred means of payment for economic transactions that economic actors seek to conceal. As such, cash stocks and flows are a natural starting point in the search for knowledge concerning the underground economy. The total amount of currency in circulation is also one of the best-measured macroeconomic indicators, since the production and distribution of currency by the government is strictly monitored and carefully recorded.<sup>1</sup> However, our knowledge concerning the location and circulation of the public’s holdings of U.S.

currency is meager. There are no reliable estimates of the varying amounts of U.S. currency circulating overseas, therefore no way of determining the domestic money supply and its change over time. This paper develops alternative means of calculating the proportions of currency held domestically and overseas and presents estimates of net outflows of U.S. currency over time. New estimates of domestic holding of U.S. currency are then used to reestimate the size and growth of the domestic underground economy.

One of the most puzzling macroeconomic anomalies is the huge amount of U.S. currency outstanding (\$390 billion) and its surprisingly persistent growth. Despite widespread predictions of the advent of the cashless society, and decades of cash-saving financial innovations, the *per capita* holdings of U.S. currency increased from \$160 in 1961 to \$1,450 by the end of 1994. Adjusting for inflation, real per capita currency increased by 70 percent, and the proportion of the M1 money supply composed of currency rose from 20 percent to 30 percent. Roughly 60 percent of the outstanding stock of currency is now in the form of \$100 bills.

The suggestion that the average American family of four now holds \$5,800 in currency, of which \$3,480 is in the form of \$100 bills, appears to be implausible. Moreover, since the average turnover rate of currency is estimated to be fifty times per year, the average American would have to be making *pro rata* cash transactions of \$72,500 per year, a figure which is plainly unbelievable. Federal Reserve surveys (Avery et al. 1986, 1987) of currency usage by American households determined that adult U.S. residents admit to holding only 12 percent of the nation's currency in circulation outside the banking system. Allowing for U.S. business holdings of currency, the whereabouts of more than 80 percent of the nation's currency supply is presently unknown. These anomalous findings give rise to the "currency enigma" (Feige 1990b, 1994a), which consists of a stock and a flow component. Our inability to identify the holders and location of a large fraction of the U.S. currency stock gives rise to a \$300 billion problem of "missing currency" (Sprenkle 1993). This missing stock of currency is used as a means of payment for the purchase of goods and services. If all of the missing currency turns over at the same rate as that estimated for U.S. households, it would effect a flow of "missing payments" amounting to almost \$15 trillion.

Two complementary hypotheses are put forward as possible explanations of the currency enigma. Some fraction of the missing currency may in fact be held by U.S. households to conduct unreported transactions in the U.S. underground economy. A considerably larger portion of the missing currency is more likely to be held abroad by foreigners who conduct transactions with U.S. dollars to effect payments in their own countries and as a store of value. This paper examines the extent to which the currency enigma can be resolved by appeal to both the underground economy hypothesis and the “world dollarization” hypothesis.

The first section of the paper presents a taxonomic framework for defining different types of underground activities, reviews alternative methods of estimation, and updates available estimates of various “underground economies” in the United States.<sup>2</sup> The following three sections describe alternative methods for estimating the amount of U.S. currency held abroad and present preliminary estimates of overseas currency holdings. These sections present a monetary demographic model (MDM) and a note ratio model (NRM) that can be employed to obtain indirect estimates of the proportions of currency held domestically and overseas, as well as direct estimates of net outflows of U.S. currency. To anticipate the results, a factor model composite measure of overseas currency flows suggests that foreigners do appear to hold a large fraction of U.S. currency, perhaps as much as 40 percent. The final section examines the implications of overseas currency holdings for the measurement of the domestic underground economy.

## **Defining and Measuring Underground Economies**

The early literature on the underground economy lacked an accepted taxonomy for classifying various underground activities. Underground activities were variously described as subterranean, irregular or informal, hidden, grey, shadow, clandestine, parallel, and black, but these descriptions were rarely augmented with explicit definitions that aided analytic and empirical investigation of the underlying phenomena. It is now well understood that there are a variety of underground economies spanning both planned and market economies, be they developed or

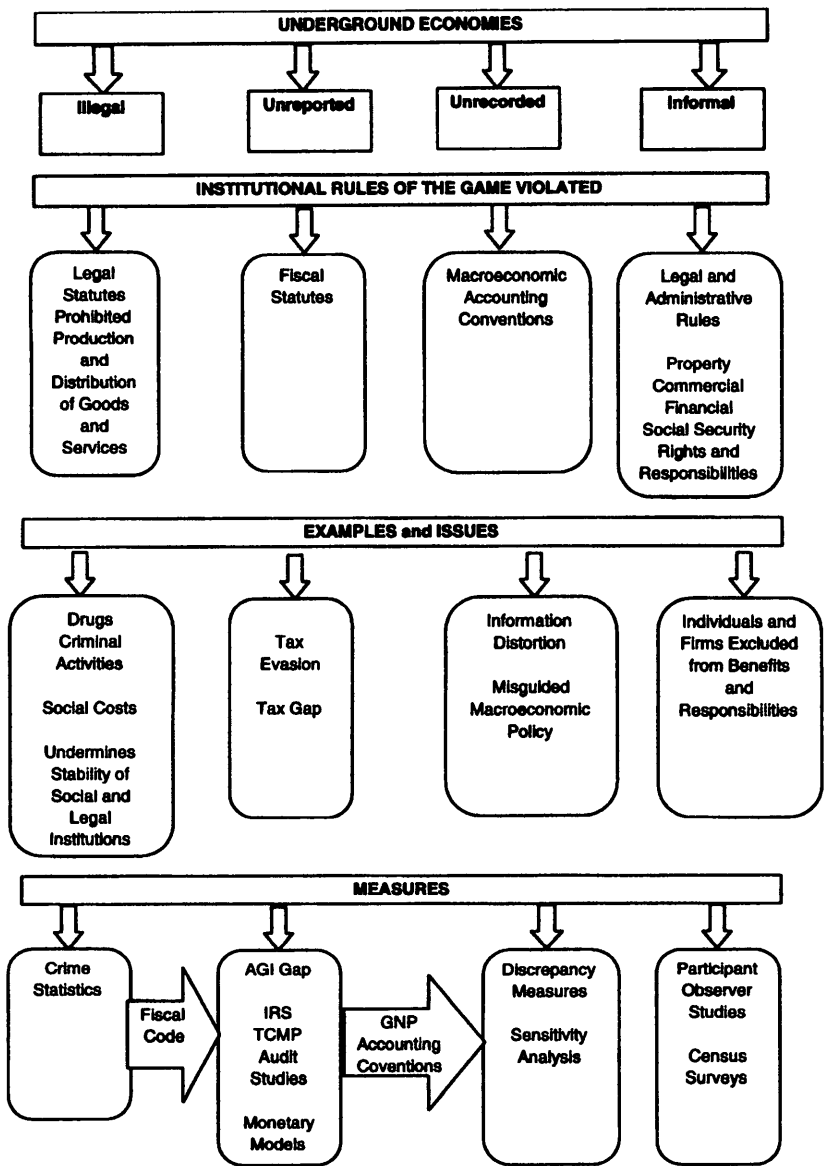
developing. Agents engaged in underground activities circumvent, escape, or are excluded from the institutional system of rules, rights, regulations, and enforcement penalties that govern formal agents engaged in production and exchange. Different types of underground activities are distinguished according to the particular institutional rules they violate. Employing this criterion, we identify four specific types of underground economic activities: illegal; unreported; and unrecorded; and informal. The metric for measuring the dimensions of each underground activity is the aggregate income generated by the activity. Figure 1 presents a taxonomy of underground economies.

The *illegal* economy consists of the income produced by those economic activities pursued in violation of legal statutes defining the scope of legitimate forms of commerce. The most notable illegal activities are the production and distribution of prohibited substances (e.g., drug traffic) and services such as prostitution, pornography, and black market currency exchange. Estimates of income produced from illegal activities are typically derived from crime-related statistics and range from \$70 to \$100 billion. In 1982, unreported income from drugs and gambling was estimated to be roughly \$26 billion (Abt Associates 1984, pp. 62, 112), and the retail value of drugs sold in the United States in 1990 was estimated to be roughly \$40 billion (Office of National Drug Control Policy 1991, p. 5).

The *unreported* economy consists of those economic activities that circumvent or evade fiscal rules as codified in the tax code. A summary measure of the unreported economy is the amount of unreported income, namely, the amount of income that should legally be reported to the tax authority but is not so reported. Since illegal income is taxable, the unreported economy includes both legal and illegal source income that is not properly reported to the fiscal authority. A complementary measure of the unreported economy is the "gross tax gap," namely, the difference between the amount of tax revenues legally due the fiscal authority and the amount of tax revenue voluntarily paid.

The "net tax gap" represents the difference between the amount of revenue due and the amount actually collected. The difference between the gross and net measures represents the revenues collected as a direct result of enforcement activities. Benefit fraud, comprising false claims for benefits (welfare or unemployment payments) or subsidies to

Figure 1.



which the individual is not legally entitled, should formally be included in “tax gap” measures.

The *unrecorded* economy consists of those economic activities that circumvent the institutional rules that define the reporting requirements of government statistical agencies. A summary measure of the unrecorded economy is the amount of unrecorded income, namely, the amount of income that should (under existing rules and conventions) be recorded in national accounting systems (e.g., National Income and Product Accounts) but is not so recorded. Unrecorded income represents a discrepancy between total income or output and the actual amount of income or output captured or enumerated by the statistical accounting system designed to measure economic activity. Since national accounting conventions differ with respect to their inclusion of illegal incomes, unrecorded income may or may not include components of the illegal sector.

The term “informal economy” has been used so frequently, and inconsistently, in the development literature that it requires special attention. The *informal* economy comprises those economic activities that circumvent the costs and are excluded from the benefits and rights incorporated in the laws and administrative rules covering property relationships, commercial licensing, labor contracts, torts, financial credit, and social security systems. A summary measure of the informal economy is the income generated by economic agents who operate informally.

Estimating the size of various underground economies remains, at best, an inexact science. However, more precise definition of alternative underground economies has reduced the tendency to compare disparate measures, and improvements in tax compliance and monetary methodologies is narrowing the range of comparable estimates.

### *Updated Estimates of Unreported Income in the United States*

Since underground economic activity typically subjects the participant to the risk of some form of sanction if discovered, agents engaged in the activity have an incentive to conceal their involvement. This propensity for secrecy creates special problems for the social science observer who attempts to measure underground behavior. A variety of direct and indirect measurements of various types of underground

activity have been proposed and each has well-known limitations (Feige 1989). Earlier empirical efforts to measure the size and growth of underground activities revealed that underground economies were large enough to be of economic significance and had grown considerably during the later half of the 1960s and throughout much of the decade of the 1970s. Costly regulation, rising tax rates, and a growing distrust of government were cited as the primary causes of increased underground activity. The conservative politics of the 1980s sought to reverse these trends by reducing government regulations, decreasing the burden of taxation, and restoring a greater sense of trust and confidence in the government by reforming the tax system and reducing what were perceived to be wasteful government expenditures. One of the questions we seek to examine is whether these efforts had any effect on reducing the size and growth of the underground economy.

Various macroeconomic measures have been mentioned as possible indicators of underground activities. These include the adjusted gross income (AGI) gap discrepancy measure produced by the Bureau of Economic Analysis (BEA); the audit-based discrepancy measures of unreported taxable income produced by the Internal Revenue Service (IRS); and estimates of unreported income derived from various specifications of monetary models. These measures are reviewed and updated.

### *Discrepancy Measures*

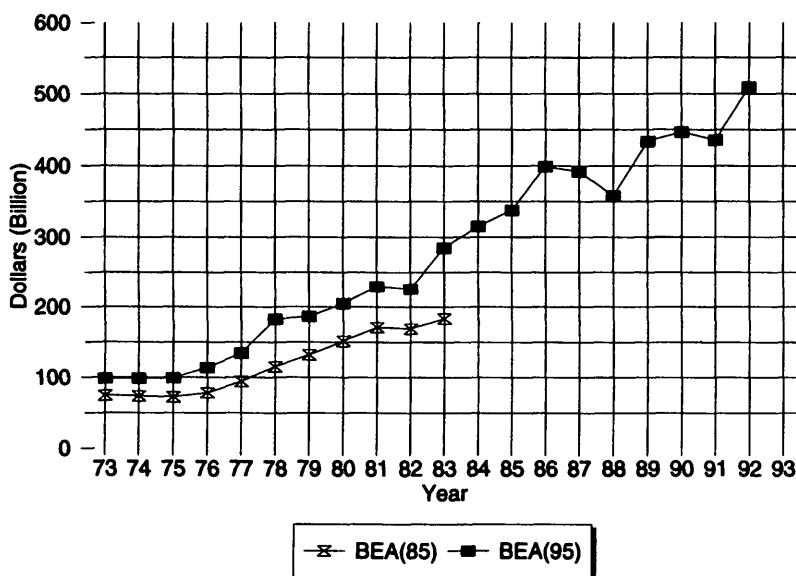
The U.S. government produces two discrepancy measures that are often cited as indicators of underground activity. The first of these, compiled by the Bureau of Economic Analysis, calculates the discrepancy between adjusted gross income as reported to the Internal Revenue Service and an independent estimate of AGI derived from National Income and Product Accounts (NIPA) estimates of personal income. This AGI gap is not officially acknowledged as a measure of the underground economy; however, with several qualifications (Carson 1984; Feige 1989), the AGI gap can be interpreted as a lower bound measure of noncompliance in the reporting of taxable income.

Figure 2 displays the AGI gap estimates published by the BEA in 1985 and the most recently revised estimates. The latest government figures reveal that the earlier gap estimates had been much too low,



requiring upward revision of \$115 billion in 1983. By 1992, the AGI gap had risen to \$500 billion. As a percentage of AGI, the gap reached its peak of 16.1 percent in 1987 and then fell to an estimated 14 percent of AGI in 1992.

**Figure 2. Adjusted Gross Income (AGI) Gap**  
Bureau of Economic Analysis Estimates



An alternative discrepancy measure of unreported income is prepared by the IRS on the basis of their Taxpayer Compliance Measurement Program (TCMP). Responding to reports of a large underground economy based on monetary estimation methods, the IRS undertook a series of studies (IRS 1979, 1981, 1983) to examine the extent of non-compliance with U.S. tax laws. Their first study (IRS 1979) concluded that in 1976, between \$75 and \$100 billion of legal source income was not properly reported on individual tax returns. The IRS estimated that the resulting revenue loss was between \$12 and \$17 billion. In addition, unreported illegal source income was estimated to be between \$25 and \$35 billion, with an added revenue loss of \$6 to \$8 billion. In their 1983 report, the estimate for legal source unreported income in 1976 was increased by \$30 billion and the associated estimated loss of

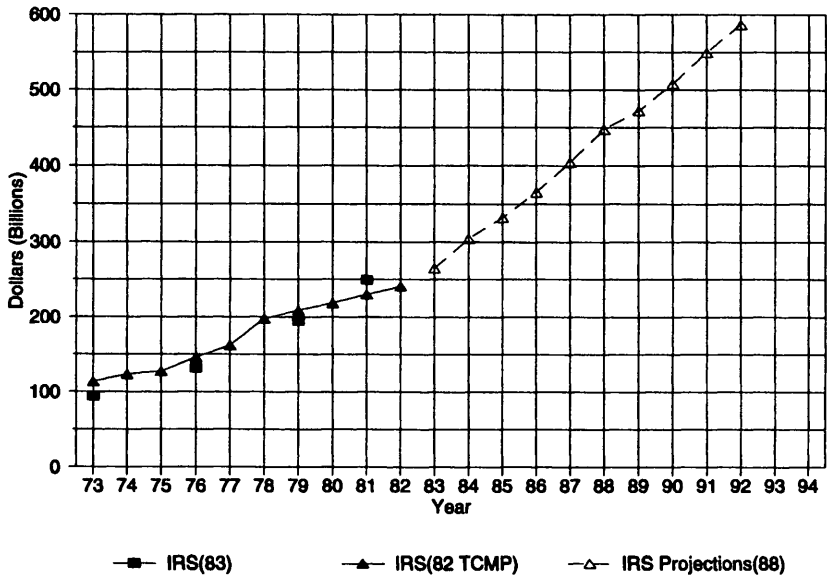
tax revenue was more than double the initial estimate. On the other hand, the 1983 report slashed the estimate of illegal source income to only \$13 billion and cut the corresponding revenue loss from the illegal sector to roughly \$4 billion.

Feige (1989) demonstrated the sensitivity of the results from the early TCMP studies to small variations in the questionable set of assumptions required to estimate magnitude of noncompliance. The admission by the IRS that 1981 total unreported income amounted to some \$283 billion and a corresponding revenue loss of \$90 billion led the BEA to undertake a major revision of the NIPA accounts. The BEA's 1985 "comprehensive revision" raised estimated personal income for 1984 by \$100 billion. Although their comprehensive revision included changes in definitions and statistical methods, the single most important element of the revision was the adjustment for income previously unrecorded due to understated tax source data. For 1984, the personal income adjustment for unrecorded wages, salaries, and nonfarm proprietor incomes amounted to \$101 billion, demonstrating the empirical connection between unreported and unrecorded income.

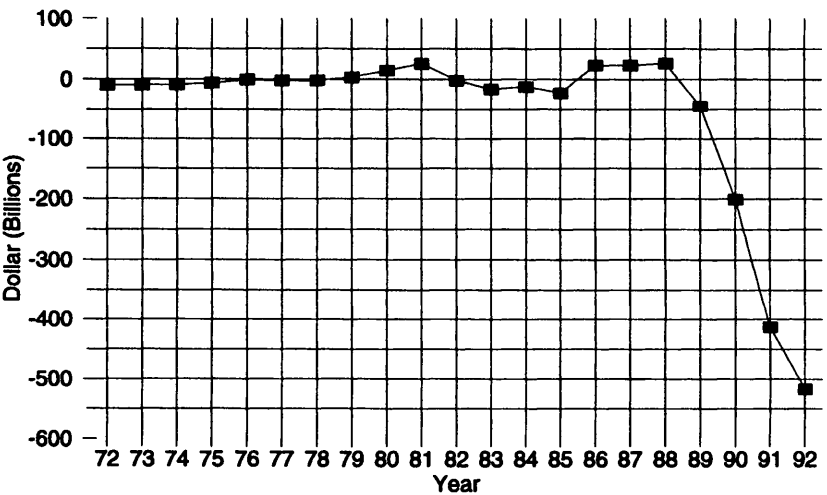
The latest IRS estimates of unreported income (IRS 1988) are based on their TCMP audits of tax returns in the years 1973, 1976, 1979, and 1982 and include estimates of unreported income and the corresponding losses in tax revenue projected out to 1992. The IRS (1988) estimates of unreported legal source income for the years 1973-1982 are presented in figure 3, along with their projected unreported income for the years 1983-1992.

In each of the audit years, a sample of roughly 55,000 tax filers was subjected to examination by IRS auditors who attempted to determine the amounts of income that should have been reported and the amounts that were unreported. Final estimates of unreported income of filers and nonfilers for those years were obtained by combining information from audits, information returns, and special surveys. The IRS projections for the period 1985-1992 were based on Office of Management and Budget forecasts of personal income combined with an assumption of constant rates of noncompliance between 1982 and 1992. The projections also assume that tax payer behavior was unaffected by the tax reforms enacted in 1986. Figure 4 depicts the discrepancy between projected AGI used in the 1988 IRS report and the actual AGI reported on subsequent tax returns.

**Figure 3. Unreported Legal Source Income  
Internal Revenue Service Estimates**



**Figure 4. IRS Projection Error in AGI  
Projected - Actual AGI**

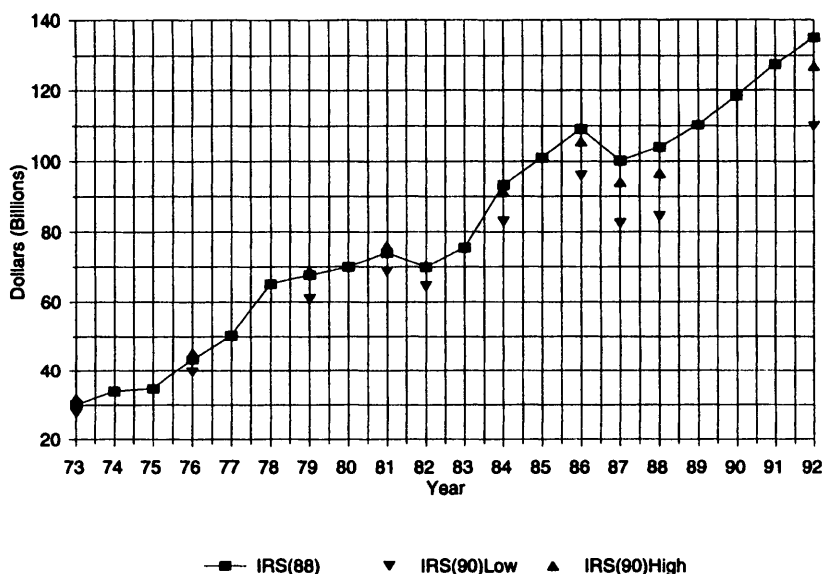


By 1992, actual reported AGI fell more than \$500 billion short of the IRS projections. The overestimates of projected reportable income and the assumption that compliance rates were unaffected by tax cuts and tax reforms suggest that the IRS projections of unreported income are overstated.<sup>3</sup>

Whereas the earlier IRS studies reported estimates of both legal and illegal source unreported income, the 1988 study is limited to estimates of unreported legal source income. The IRS (1983) study estimated that in 1981, illegal source income amounted to \$34.2 billion, or roughly 15 percent of the revised legal source estimate for 1981. If illegal income remained at roughly the same percentage as legal income, it would add an additional \$88 billion of unreported illegal source income to the estimate of \$585 billion of unreported legal source income for 1992.<sup>4</sup>

Figure 5 reports alternative IRS estimates of the “gross tax gap” on legal source income of individuals and corporations. The gross tax gap

**Figure 5. Estimates of the Gross Tax Gap  
Legal Source Income**



overstates the amount of revenue lost to the government due to non-compliance to the extent that IRS enforcement activities collect some

of the amounts due. The yield from these enforcement activities was estimated to be \$15.4 billion in 1981, \$18.9 billion in 1984, and \$21.9 billion in 1987 (IRS 1990, table 2, p. 10). The gross tax gap understates the loss of revenue to the government because it excludes revenue lost on illegal source income as well as revenue losses from noncompliance with other federal taxes including employment, excise, gift, and estate taxes and customs duties. For the year 1987, income taxes accounted for only 56 percent of federal budget receipts. Another 36 percent came from employment taxes and 5 percent from gift, estate, and excise taxes. There is virtually no information available on the revenue losses from noncompliance with these other important revenue sources, nor are there estimates of the amount of government expenditures wasted as a result of benefit fraud.

### *Currency Ratio Models*

The most common method for estimating the size of the unreported economy relies on some variant of the general currency ratio model described in Feige (1989). The most restrictive specification of the currency ratio model (Cagan 1958; Gutmann 1977) assumes that currency is the exclusive medium of exchange for unreported transactions, that the ratio of currency to checkable deposits is only affected by the growth of unreported transactions, that the income velocities of reported and unreported transactions are identical, and that in some base period, unreported income was zero so that the observed base period currency deposit ratio serves as a proxy for the desired currency ratio in the official economy.<sup>5</sup>

Figure 6 displays estimated unreported income as a percent of recorded AGI as obtained from the simple currency ratio model under the assumptions that in 1940 there was no unreported income and that all currency outside of the banking system was held by the domestic public. As has been noted in earlier studies, the ratio of unreported income rose sharply during World War II and then declined and remained relatively stable until the early 1960s. Unreported income then grew from less than 5 percent of AGI in 1960 to 15 percent by 1980.

The percentage of unreported income reached a plateau during the early 1980s and actually declined around the time of the 1986 Tax

Reform Act. The percent of unreported income then rose steeply between 1987 and 1991. Figure 6 also presents the results of a more general specification of the currency ratio model.<sup>6</sup> The general currency ratio model (GCR) employs the IRS estimate of unreported income for 1973 as an appropriate benchmark; it assumes that 75 percent of unreported income transactions are effected by currency and that the remaining 25 percent are effected by checkable deposits. The resulting estimates display a time path similar to that of the more restrictive estimates, however the percent of unreported activities is considerably higher in all periods.

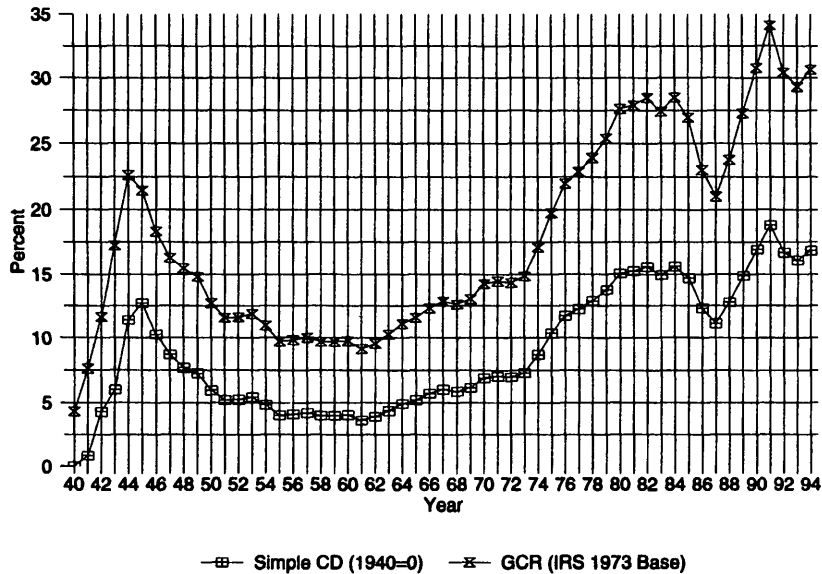
Figure 7 displays three estimates of total unreported income from both legal and illegal sources for the period 1972 through 1993.<sup>7</sup> The IRS projections are remarkably similar to those obtained by the simple currency ratio model suggesting that by 1991, total unreported income amounted to roughly \$650 billion or 17 percent of reported AGI.

Assuming that this unreported income had been subject to a marginal income tax rate of 20 percent, \$130 billion of income tax revenues would have escaped government collection, roughly 62 percent of the federal budget deficit.

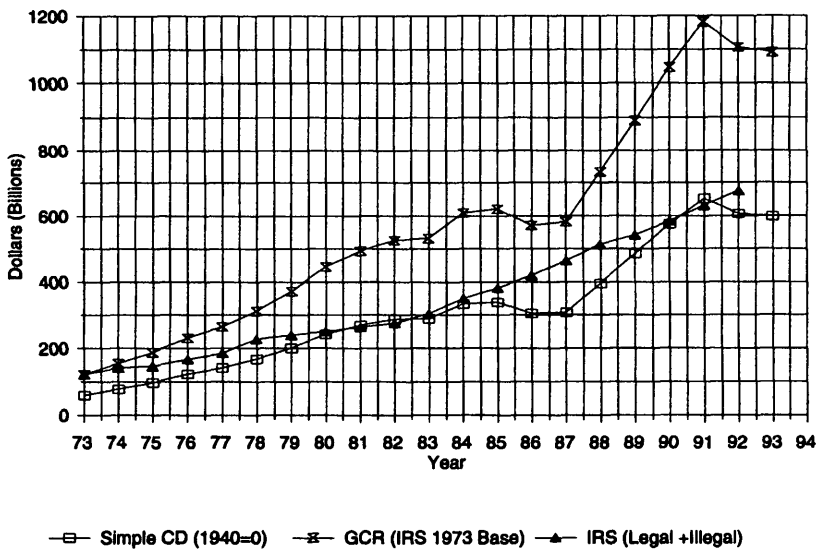
The GCR model results suggest that unreported income grew gradually during the first half of the 1980s, declined in the mid-1980s and then resumed its growth until the early 1990s. Unreported income appears to have doubled during the last half of the decade and exceeded \$1 trillion during the early 1990s. All of these currency ratio model estimates are predicated on the assumption that U.S. currency is exclusively used to effect domestic transactions in either the official or the underground economy. There is, however, a growing body of anecdotal evidence suggesting that U.S. currency also circulates as a medium of exchange in foreign countries. If a large and perhaps variable fraction of U.S. currency is held outside of the U.S., this would tend to overstate the size of the domestic underground economy as estimated by conventional currency ratio models.

Federal Reserve (Avery et al. 1986, 1987) Surveys of Currency and Transaction Account Usage (SCTAU) reinforce the notion that a substantial portion of U.S. currency holdings cannot be accounted for by the behavior of U.S. households. In both 1984 and 1986, SCTAU determined that U.S. households admitted to holding at most 12 percent of the nation's currency supply. Since business firms are very concerned

**Figure 6. Unreported Income as Percent of AGI**  
**Currency Ratio Models**



**Figure 7. Estimated Total Unreported Income**  
**Currency Ratio Models and IRS Estimate**



with efficient cash management in order to minimize interest losses associated with cash inventories, they are likely to hold considerably smaller cash inventories than households. The scant evidence on U.S. currency holdings by business firms (Anderson 1977; Sumner 1990) suggests that domestic firms hold less than 3 percent of currency in circulation.

A conservative estimate of the stock of currency required to sustain the estimated cash payments made in the unreported economy can be obtained by employing the IRS projection that total unreported income in 1992 amounted to \$675 billion. Assuming that roughly 75 percent of this unreported income is effected by cash and taking currency turnover (the income velocity of currency) to be roughly fifty turnovers per year yields a stock of currency used for underground transactions that is less than 4 percent of currency in circulation with the public.<sup>8</sup> In short, since U.S. households admit to holding only 12 percent of the nation's currency in circulation, firms hold roughly 3 percent, and underground transactions absorb another 4 percent, the ownership of roughly 80 percent of circulating U.S. currency is currently unknown. This anomaly of missing currency gives rise to the stock component of the "currency enigma" (Feige 1994a). A similar problem arises with attempts to allocate the flow of payments sustained by the outstanding currency stock to different sectors of the economy. The admitted household holdings of 12 percent of U.S. currency circulating outside of the banking system give rise to an estimated volume of cash payments of \$1.7 trillion for 1992, roughly 41 percent of recorded personal consumption expenditures. Estimated cash holdings of business firms analogously give rise to some \$400 billion of intermediate payments, amounting to roughly 7 percent of total intermediate payments. An additional \$675 billion of cash payments can be allocated to underground transactions. If the stock of the remaining "missing" currency circulates at roughly the same rate as currency held by U.S. households, it would give rise to an additional volume of unaccounted cash payments in excess of \$10 trillion.

Several hypotheses have been put forward to explain these monetary anomalies. One explanation is that the U.S. underground economy is substantially larger than current estimates suggest, and that domestic holdings of U.S. currency are much larger than the amounts of currency households admit to holding on currency surveys. The more



plausible “world dollarization” hypothesis suggests that a substantial fraction of U.S. currency is held abroad by residents of other nations. The complementary “hoarding” hypothesis suggests that overseas holdings of U.S. currency are largely held as stores of value rather than being used as a medium of exchange. The dollarization hypothesis requires independent estimates of the fraction of U.S. currency held abroad. The hoarding hypothesis requires evidence confirming that overseas holdings of U.S. currency circulate at slower rates than domestic currency holdings.

Anecdotal reports of U.S. currency circulating in parts of Latin America, the Middle East, Eastern Europe, and Russia are widespread, as are suggestions that foreign demand for U.S. currency can fluctuate quite dramatically. Since the size, variability, and velocity of foreign holdings of U.S. currency have important implications for the measurement of the domestic underground economy and for the conduct of domestic monetary policy, we turn our attention to efforts to locate the “missing” U.S. currency.

### **Indirect Methods for Estimating Foreign Holdings of U.S. Currency**

Although there is much anecdotal evidence concerning the widespread use of U.S. currency overseas, until very recently there was no systematic research undertaken to determine the location of the U.S. currency supply. Several different approaches are presently being explored to estimate both the stock of foreign holdings of U.S. currency and the migration of currency into and out of the country.<sup>9</sup>

The introduction in 1996 of a newly designed U.S. currency series with modern counterfeit protection provides a unique opportunity to establish a currency census system (CCS), which *while fully preserving the anonymity of individual currency usage*, could monitor key characteristics of the currency population. Relevant information on the life cycle of a currency note could be electronically captured as notes are routinely and anonymously processed by high-speed sorting machines when they are issued and returned to the Federal Reserve Banks. The proposed CCS would eliminate any burden of human

reporting. By maintaining automated records of a note's age, quality, birthplace, location, and final redemption, a CCS information system would provide the data required to construct currency migration matrices and all other demographic characteristics of the note population.<sup>10</sup> In the absence of a location-specific enumeration of currency holdings, it is necessary to rely on direct sources of information concerning inflows and outflows of U.S. currency as well as on indirect methods for estimating the changing proportion of U.S. notes held overseas.

### *The Monetary Demography Model*

This section develops a model capable of estimating the proportions of notes held domestically and overseas. Given estimates of these proportions and knowledge of the total stock of currency outstanding, one can estimate the overseas stock of currency and also obtain estimates of net currency outflows from the changes in foreign holdings over time. The proportion of U.S. currency circulating domestically ( $\beta^d$ ) and the proportion circulating overseas ( $\beta^o$ ) can be estimated from a simple monetary demography model (MDM) of the currency population.

Consider the general problem of estimating the proportions  $P_1$  and  $P_2$  of members in two subpopulations  $C_1$  and  $C_2$  which comprise the total population  $C$ . Let  $X$  represent any characteristic of the total population  $C$ , and  $X_1$  and  $X_2$  respectively represent the corresponding characteristic of the subpopulations  $C_1$  and  $C_2$ . The unknown proportions  $P_1$  and  $P_2$  can then be derived from the following equation:

$$(Eq. 1) \quad X = P_1 \cdot X_1 + P_2 \cdot X_2.$$

Since  $P_1 + P_2 = 1$ , it follows that:

$$(Eq. 2) \quad \begin{aligned} P_1 &= (X - X_2) / (X_1 - X_2) \quad \text{and} \\ P_2 &= (X_1 - X) / (X_1 - X_2). \end{aligned}$$

A meaningful solution for the parameters  $P_1$  and  $P_2$  exists so long as the characteristics of the subpopulations are different ( $X_1 \neq X_2$ ), and the calculated proportions lie between 0 and 1. For example, if we know that the average weekly income ( $X$ ) of the entire U.S. population is \$600 and the average weekly income of the population located east of

the Mississippi is \$800 ( $X_1$ ) and the average weekly income of the population west of the Mississippi is \$500 ( $X_2$ ), it follows that one-third of the population lives in the eastern portion of the country and two-thirds of the population lives in the western portion.

This simple demographic model can be generalized to find the proportion of members in any exhaustive set of subpopulations so long as the characteristics describing the subpopulations are different. In the foregoing example, the characteristic measure was simply a scalar representing the mean of the income distribution for the entire population and for each of the subpopulations. More generally, the characteristics ( $X$ ,  $X_1$ , and  $X_2$ ) may be vectors representing univariate or multivariate distributions of the total and subpopulation characteristics. Examples of measurable characteristics which might be employed to estimate the MDM are the age, quality, velocity, denomination, series, or seasonal characteristics of the total and subpopulations.

Given estimates of any note population characteristic  $X$ , and the corresponding domestic ( $X^d$ ) and overseas ( $X^o$ ) note characteristics, the proportion of notes circulating domestically ( $\beta^d$ ) can be estimated as:

$$(\text{Eq. 3}) \quad (\beta^d) = (X - X^o) / (X^d - X^o).$$

#### *The MDM employing age and quality characteristics*

Applying general demographic concepts to currency populations leads naturally to a consideration of possible differences in the age and quality characteristics of denomination-specific notes circulating domestically and overseas. Estimates of the age, quality, and quality by age distributions of the domestic and overseas subpopulations were obtained from a special study conducted by the Federal Reserve.<sup>11</sup> Based on a sample of some four million individual notes, note quality was ascertained by recording light reflectivity measures from an optical desitometer that scanned individual notes during routine note processing by high-speed sorting machines located at Federal Reserve Banks in each of the twelve Federal Reserve Districts. Individual note serial numbers were recorded for a subsample of approximately 150,000 notes drawn from domestic and overseas sources in order to determine the date on which each note was sent by the Bureau of Engraving and Printing to a Federal Reserve Bank. An inventory model was then employed to estimate the date the note was actually placed

into circulation, thereby establishing its date of birth. Each note's age was then determined as the difference between the sample date and the note's date of birth. Therefore, for each note denomination (\$1; \$5; \$10; \$20; \$50; \$100) it was possible to construct the univariate age and quality distributions for notes sampled domestically and overseas.

Casual observation suggests that domestic notes are likely to be used predominantly as a medium of exchange, whereas overseas notes are more likely to be held as a store of value. Thus for any denomination, it was expected that the univariate age and quality distributions of domestic and overseas notes and the corresponding bivariate quality by age distributions would differ greatly. Domestic notes, sampled on their return to the Federal Reserve, were expected to be relatively younger than overseas notes and generally of poorer quality for a given age. Given these expected differences in domestic and overseas characteristics, age, quality, and quality by age distributions were thought to be promising characteristics for estimating the proportion of notes held overseas.

Surprisingly, preliminary analysis of the quality and quality by age distributions of the domestic and overseas samples revealed that they were not sufficiently different to obtain robust estimates of the proportions of notes held domestically and overseas. Initial efforts to estimate the MDM were therefore based on differences in the univariate age distributions between overseas and domestic notes for each specific note denomination population. Denomination-specific age distributions for the entire note population were derived from FR-160 data on note births and deaths (redemptions) combined with estimates of average note lifetimes.

Employing the age characteristics of the relevant populations, the problem then is to estimate the proportion of U.S. currency circulating domestically ( $\beta^d$ ) and the proportion circulating overseas ( $\beta^o = 1 - \beta^d$ ) from the MDM(A) specified for each denomination as follows:

$$(\text{Eq. 4}) \quad A = \beta^d A^d + (1 - \beta^d) A^o, \text{ and}$$

$$\beta^d = (A - A^o) / (A^d - A^o)$$

where  $A$ ,  $A^d$  and  $A^o$  represent the denomination-specific age distributions for the total, domestic, and overseas note populations, respec-

tively. Estimates of the proportion of notes of different denominations circulating abroad in mid-1989 were then obtained from estimates of the overall, domestic, and overseas age distribution of the notes.<sup>12</sup>

Table 1 presents the resulting denomination-specific estimates of the proportion of notes held overseas. The MDM model estimated for the

**Table 1. Estimates of the Demographic Model**  
 $\{MDM[C^{den l}; C^{den l d}; C^{den l o}]; (A)\}$   
**Age Distribution Characteristics**

<b>Denomination</b>	<b>Estimated share of each denomination overseas 1989 (percent)</b>	<b>\$ value of notes in circulation 1989 (billions)</b>	<b>\$ value of notes overseas 1989 (billions)</b>	<b>Denomination composition of overseas currency (percent)</b>
\$1	35.7	4.00	1.43	1.57
\$5	37.6	4.99	1.88	2.07
\$10	19.3 - 35.0	10.25	1.98 - 3.59	3.95
\$20	49.0 - 69.3	54.67	21.86 - 37.89	24.09
\$50	45.3	26.25	11.89	13.10
\$100	51.1	98.17	50.12	55.21
<b>Total</b>	<b>45.8 - 53.0</b>	<b>198.33</b>	<b>89.2 - 106.8</b>	<b>100.0</b>

age distribution characteristics suggests that in 1989, between 45.8 and 53 percent of the U.S. currency stock was held overseas. Of these overseas holdings, 68.3 percent was held in the form of large denomination bills (\$100 and \$50); approximately 28 percent was held in mid-sized denomination bills (\$20 and \$10) and 3.6 percent was held in the form of small denomination bills (\$5 and \$1).

*The MDM employing seasonality, series, and coin/bill ratio characteristics*

Porter and Judson (1995) employ several variants of the MDM to estimate the proportion of currency held overseas by exploiting

assumed differences in the seasonality, series, and coin/bill ratio characteristics of domestic and overseas holdings of U.S. currency.

Since the seasonal component characteristic of the total U.S. currency population ( $S$ ) is directly measurable, but the seasonal characteristics of the domestic ( $S^d$ ) and foreign ( $S^o$ ) are unobservable, Porter and Judson assume that for the period 1947-1994, the seasonal component of domestic U.S. currency holdings is identical to the observed seasonal pattern of the Canadian currency supply.<sup>13</sup> They furthermore assume that there is no significant seasonal component in the foreign demand for U.S. currency, so that the seasonal characteristic of overseas holding of U.S. currency ( $S^o$ ) can be assumed to be equal to unity. The seasonal variant of the MDM( $S$ ) model can then be estimated from the equation:

$$(Eq. 5) \quad S = \beta^d S^d + (1 - \beta^d) S^o$$

where the seasonal characteristics are time dependent and:

$$\begin{aligned} S &= S^{US} \\ S^d &\approx S^{CAN} \\ S^o &\approx 1. \end{aligned}$$

From Equation (3), it follows that the domestic share of currency holdings ( $\beta^d$ ) is estimated as:

$$(Eq. 6) \quad \beta^d = (S - 1) / (S^d - 1).$$

Table 2 presents Porter and Judson's reported estimates of the denomination-specific share of U.S. currency held overseas for 1989. The denomination-specific MDM( $S$ ) yields an overall estimated proportion of currency abroad of 62.4 percent for 1989 compared to the estimated range of 45.8 to 53.0 percent from the MDM(A) age characteristic model. Concerning the composition of the currency held abroad, the MDM( $S$ ) results suggest that 67.8 percent of foreign holdings are in the form of large denomination bills, and correspondingly 29.7 percent and 2.5 percent are held in the form of mid-sized and small denomination notes.

A second variant of the MDM estimated by Porter and Judson exploits differences between the series composition characteristic ( $SR$ ) of domestic and overseas notes to estimate the proportion of \$100 and

\$50 circulating abroad. In 1991, the Federal Reserve introduced a 1990 series note which was distinguished from the pre-1990 series notes in circulation by a polyester strip and microprinting to deter counterfeiting. Let the series composition characteristic ( $SR$ ) be the proportion of the circulating note population ( $N$ ) made up of new 1990 series notes ( $N^{90}$ ) so that  $(SR) = N^{90} / N$ .

**Table 2. Estimates of the Demographic Model**  
**{MDM[ $C^{den i}$ ;  $C^{den i d}$ ;  $C^{den i o}$ ];(S)}**  
**Annual Seasonal Characteristics**

<b>Denomination</b>	<b>Estimated share of each denomination overseas 1989 (percent)</b>	<b>\$ value of outstanding notes 1989 (billions)</b>	<b>\$ value of notes overseas 1989 (billions)</b>	<b>Denomination composition of overseas currency (percent)</b>
\$1	10.0	4.00	0.40	0.32
\$5	54.2	4.99	2.70	2.18
\$10	44.2	10.25	4.53	3.66
\$20	59.1	54.67	32.31	26.09
\$50	50.7	26.25	13.31	10.75
\$100	72.0	98.17	70.60	57.00
<b>Total</b>	<b>62.4</b>	<b>198.33</b>	<b>123.85</b>	<b>100.0</b>

Since the series composition of the total currency population is known, Porter and Judson require estimates of ( $SR$ ) for both the domestic and overseas components. They assume that the series composition of "overseas" notes is adequately proxied by an estimate of the series composition of notes processed by the New York Federal Reserve, and that an estimate of the series composition of the notes processed by all other Federal Reserve Banks adequately reflects the "domestic" composition.<sup>14</sup> The  $MDM(SR)$  for series composition can then be represented as:

$$(Eq. 8) \quad SR = \beta^d SR^d + (1 - \beta^d) SR^o$$

where:

$(SR) = N^{90} / N$  is known and, by assumption,

$$SR^d \approx SR^{NonNY}$$

$$SR^o \approx SR^{NY}$$

The proportion of notes held domestically can be estimated as:

$$(Eq. 9) \quad \beta^d = (SR - SR^o) / (SR^d - SR^o) \approx (SR - SR^{NY}) / (SR^{NonNY} - SR^{NY}).$$

Porter and Judson employ two different procedures for estimating the domestic and overseas series composition characteristics, and table 3 presents their upper and lower bound estimates for the \$50 and \$100 denominations.

**Table 3. Estimates of the Demographic Model**

$\{MDM[C^{den l}; C^{den l d}; C^{den l o}]; (SR)\}$

$\{MDM[C; C^d; C^o]; (C/N)\}$

**Series and Coin or Coin/Note Ratio Characteristics**

	Estimated share of each denomination overseas 1994 (percent)	Estimated share of each denomination overseas 1994 (percent)	Estimated share of each denomination overseas 1994 (percent)	Estimated share of overseas currency 1989 (percent)
Denomination	Lower bound series model	Upper bound series model	Average series model	Coin ratio
\$1-\$20	n.a.	n.a.	n.a.	n.a.
\$50	28.0	48.0	38.0	n.a.
\$100	55.6	70.7	63.2	n.a.
Total	n.a.	n.a.	n.a.	20.9

A third variant of the MDM employs the ratio of coins to notes as the characteristic distinguishing domestic and overseas holdings of currency. Since the coin/note ratio of the total U.S. currency population



is directly observable, it remains to identify the coin/note ratio of domestic and overseas holdings. Porter and Judson assume that the domestic coin ratio can be represented by Canada's coin/note ratio and that the overseas ratio is identically zero since virtually no U.S. coin is held overseas. Let  $C/N$  represent the population ratio of coins to notes,  $(C/N)^d$  represent the domestic coin ratio, and  $(C/N)^o$  the overseas coin ratio. If  $\beta^d$  represents the fraction of U.S. currency held domestically, then it follows from equation (3) that the  $MDM(C/N)$  can be represented as:

$$(Eq. 10) \quad (C/N) \approx \beta^d (C/N)^d + (1 - \beta^d) (C/N)^o.$$

By assumption,

$$(C/N)^d \approx (C/N)^{CAN} \text{ and}$$

$$(C/N)^o \approx 0$$

therefore, (Equation 3) reduces to:

$$(Eq. 11) \quad \beta^d = (C/N) / (C/N)^{CAN}.$$

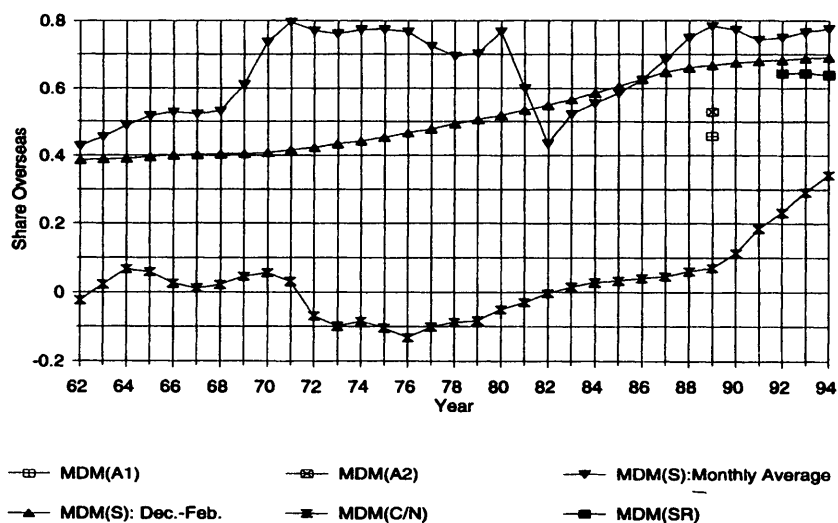
As displayed in table 3, Porter and Judson's  $MDM(C/N)$  estimate of the share of U.S. currency held abroad in 1989 is 20.9 percent.<sup>15</sup>

In order to examine the robustness of the  $MDM(S)$  results presented by Porter and Judson, the model was reestimated employing the X11 ARIMA method for calculating the multiplicative seasonal component of notes in circulation for the United States and Canada.<sup>16</sup> Our reestimation of the  $MDM(S)$  confirms the Porter and Judson findings that the model is incapable of producing sensible estimates at monthly or quarterly frequencies. In particular, monthly and quarterly estimates of the overseas share of U.S. currency reveal a strong seasonal component, suggesting that the assumption that  $(S^o \approx 1)$  may be unsustainable. Even annual time series estimates of the overseas shares obtained from the annual average of monthly seasonal components is quite different from that derived by Porter and Judson, employing a seasonal amplitude metric of the difference between the December and February sea-

sonals. Figure 8 presents the Porter and Judson time series of the estimated share overseas [MDM(S):DEC-FEB] and the corresponding estimate based on the average of monthly seasonal components [MDM(S):Monthly Average]. The figure also includes the range of 1989 point estimates from the age characteristic model [MDM(A1)] and [MDM(A2)], the overseas shares derived from the coin ratio model [MDM(C/N)], and the average share of \$100 notes derived from the series characteristic model [MDM(SR)].

As displayed in figure 8, the monetary demography models produce a wide range of estimates of the overseas share of U.S. currency and different temporal patterns of the change in overseas holdings. Given the diversity of results, and the strong assumptions required to produce them, it is difficult to place much confidence in the foregoing findings.

**Figure 8. Share of U.S. Currency Overseas**  
**Monetary Demography Model Estimates**



The age characteristic model required the elimination of sample outliers before convergence could be obtained. The coin ratio model produces negative overseas shares for the period 1972-82, and the seasonal characteristic estimates produce implausible results at monthly and quarterly frequencies. Both the seasonal and serial characteristic models require strong assumptions concerning the unob-

served domestic and overseas characteristic specifications. Given these difficulties, we now turn to several alternative approaches for estimating the share of U.S. currency held abroad.

### *Note Ratio Models*

The Note Ratio Model (NRM) provides an alternative means for obtaining indirect estimates of the share of currency held abroad. The known amount of U.S. notes in circulation ( $N$ ) can be decomposed into the unknown amount of notes in domestic circulation ( $N^d$ ) and the unknown amount circulating overseas ( $N^o$ ). Let  $Z$  denote any variable that is assumed to affect the demand for notes. Then,

$$(Eq. 12) \quad N/Z = N^d/Z + N^o/Z.$$

As with the MDM models, assume that the domestic U.S. ratio can be proxied by the same ratio in Canada so that:

$$N^d/Z \approx (N/Z)^{CAN}.$$

Substituting the Canadian ratio  $[(N/Z)^{CAN}]$  into Equation (12), multiplying through by  $Z$  and dividing both sides by  $N$  yields a solution for the unknown fraction of notes overseas ( $\beta^o$ ).

$$(Eq. 13) \quad (\beta^o) = N^o/N = [N - (N/Z)^{CAN} \cdot Z]/N.$$

The simple note ratio model (NRM) is estimated for several variants where  $Z$  alternatively represents:

- (i) Personal Consumption Expenditures (PCE)
- (ii) Personal Disposable Income (PDI)
- (iii) Population (POP) x Consumer Price Index (CPI).

Figure 9 presents the estimated share of U.S. currency held overseas from each of the variants of the note ratio model: NRM(PCE), NRM(PDI), and NRM(POP, CPI). The results suggest that the share of U.S. notes held overseas declined for almost a decade between the early 1960s and the early 1970s and then rose significantly over the

next two decades. The peak in overseas holdings appears to have occurred in 1990 when roughly 30 to 35 percent of U.S. notes in circulation are estimated to be held abroad. The time series of estimated shares of currency held abroad derived from the note ratio models yield markedly lower shares abroad than those estimated by the seasonal variant of the MDM and higher shares than those estimated by the MDM(C/N).

**Figure 9. Share of U.S. Currency Overseas  
Note Ratio Models**

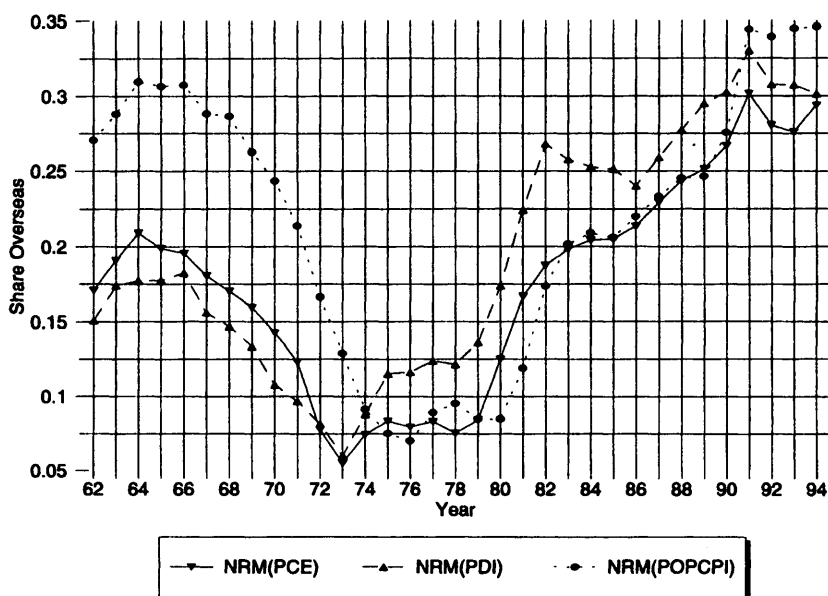


Table 4 presents the correlation matrix of annual estimates of the share of currency overseas obtained from each of the indirect methods. The correlation matrix reveals relatively high correlations between all of the NRM estimates and the MDM(C/N) estimate of overseas shares. Comparing the MDM(S) estimate obtained from annual averages of the estimated monthly seasonal components with the MDM(S):Dec.-Feb. estimate (employing the difference between December and February seasonal components) reveals that the two alternative methods of computing the seasonal estimates yield very different results. The cor-

**Table 4. Correlation Matrix of Indirect Annual Estimates of Share of Currency Overseas: 1962-1994**

	<b>MDM(C/N)</b>	<b>MDM(S)</b>	<b>MDM(S):Dec.-Feb.</b>	<b>NRM(PCE)</b>	<b>NRM(PDI)</b>	<b>NRM(POP,CPI)</b>
<b>MDM(C/N)</b>	1.000	0.079	0.601	0.879	0.744	0.835
<b>MDM(S)</b>	0.079	1.000	0.393	-0.136	-0.026	-0.301
<b>MDM(S):Dec.-Feb.</b>	0.601	0.393	1.000	0.678	0.864	0.231
<b>NRM(PCE)</b>	0.879	-0.136	0.678	1.000	0.916	0.828
<b>NRM(PDI)</b>	0.744	-0.026	0.864	0.916	1.000	0.552
<b>NRM(POP,CPI)</b>	0.835	-0.301	0.231	0.828	0.552	1.000

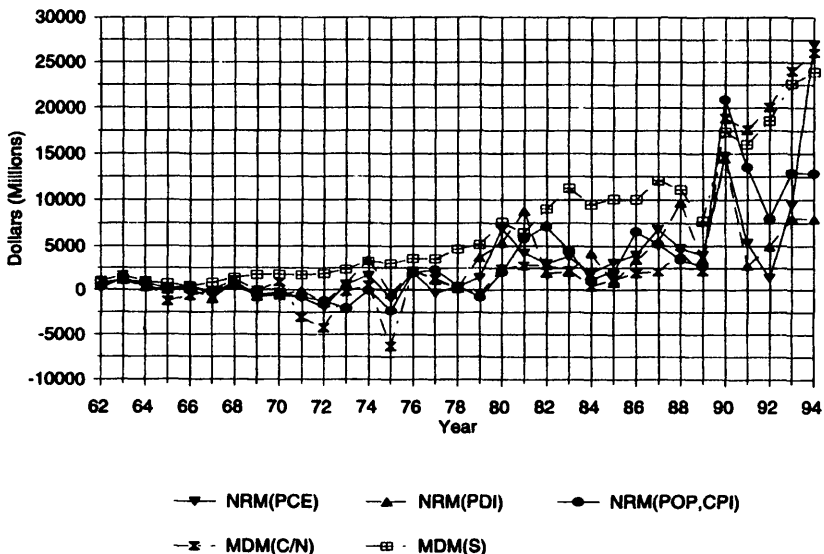
relation between the two seasonal model estimates is only .393, suggesting that the model is quite sensitive to the arbitrary choice of a metric. The MDM(S) displays low and negative correlations with the other estimates, whereas the smoothed MDM(S):Dec.-Feb. series displays positive correlations with the other estimates.

### *Indirect Estimates of Net Outflows of U.S. Currency*

Given the wide range of estimates of the share of currency abroad produced by different models, we turn our attention to estimating the net outflows of currency implied by each of the MDM and NRM models. Given the known total stock of notes in circulation and indirect estimates of the share of currency abroad, we obtain year-end estimates of the total stock of currency estimated to be held abroad.<sup>17</sup> The difference in these estimated year-end overseas stocks yields estimates of the annual net outflows of currency from the U.S.

Table 5 displays the correlation matrix of the estimated net outflows derived from each of the indirect methods, and figure 10 displays the estimated net outflows. The net outflow estimates from the different

**Figure 10. Annual Net Outflows of U.S. Currency  
NRM and MDM Estimates**



**Table 5. Correlation Matrix of Annual Estimates of Net Outflows of Currency Overseas: 1962-1994**

	<b>MDM(C/N)</b>	<b>MDM(S)</b>	<b>MDM(S):Dec.-Feb.</b>	<b>NRM(PCE)</b>	<b>NRM(PDI)</b>	<b>NRM(POP,CPI)</b>
<b>MDM(C/N)</b>	1.000	0.884	0.859	0.770	0.660	0.872
<b>MDM(S)</b>	0.884	1.000	0.990	0.793	0.732	0.853
<b>MDM(S):Dec.-Feb.</b>	0.859	0.990	1.000	0.791	0.758	0.847
<b>NRM(PCE)</b>	0.770	0.793	0.791	1.000	0.726	0.763
<b>NRM(PDI)</b>	0.660	0.732	0.758	0.726	1.000	0.769
<b>NRM(POP,CPI)</b>	0.872	0.853	0.847	0.763	0.769	1.000

**Table 6. Means and Standard Deviations of Indirect Annual Net Outflow Estimates (\$ Millions)**

	<b>MDM(C/N)</b>	<b>MDM(S)</b>	<b>MDM(S):Dec.-Feb.</b>	<b>NRM(PCE)</b>	<b>NRM(PDI)</b>	<b>NRM(POP,CPI)</b>
<b>Mean</b>	3,704	7,041	7,122	3,148	2,834	3,297
<b>Std. Dev.</b>	7,938	6,627	6,593	5,502	3,653	5,279

models appear to be more highly correlated with one another than the estimated net outflows. The net outflow estimates from the different models appear to be more highly correlated with one another than the share estimates, suggesting that the indirect methods may produce more accurate estimates of outflows than shares abroad. The major difference between the estimated net outflows is their magnitudes. As displayed in table 6, the MDM seasonal estimates yield average annual outflows that exceed the highest estimate produced by the other models by more than \$3.3 billion per year. Given these disparities, we turn our attention to direct estimates of net outflows of U.S. currency.

### **Direct Estimates of Net Outflows of U.S. Currency**

Large shipments of U.S. currency into and out of the United States are typically handled by a small number of commercial banks that specialize in the business of bulk currency transport. These large currency shipments have been informally reported to the Federal Reserve Bank of New York cash office since 1988. Although the period spanned by these confidential estimates is short, and the data are not comprehensive, being limited to major shippers operating in the New York Federal Reserve District, they provide useful information on a portion of bulk cash shipments to and from the United States.<sup>18</sup> Interviews with Federal Reserve officials suggest that much of the currency employed for bulk overseas currency shipments by the major transporting banks is supplied by the New York Federal Reserve Bank in the form of \$100 denomination notes. Employing FR-160 data, Feige (1994a) observed a correlation of .979 between the net value of \$100 denomination notes (NYNET) injected into circulation by the New York Federal Reserve and the net amount of currency shipped overseas as recorded in the confidential data series on bulk shipments abroad informally collected by the New York Federal Reserve Bank. Feige (1994a) employed (NYNET) as a proxy for net outflows of bulk currency shipments for the period 1974-1988, and this proxy was subsequently used by Porter and Judson (1995) as a proxy measure of total currency flows overseas.

The second direct measure of currency inflows and outflows is collected as part of the regulatory responsibility of the U.S. Customs Ser-



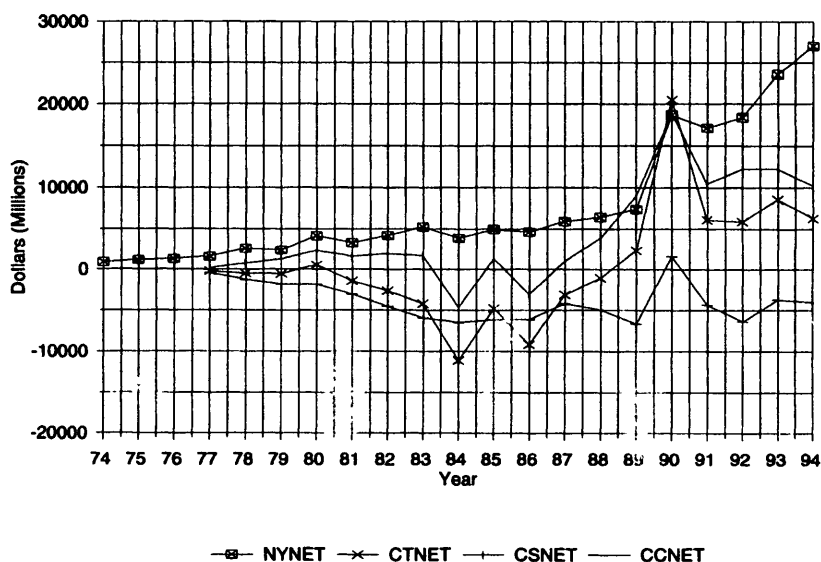
vice. Enacted in October 1970, the Currency and Foreign Transactions Reporting Act (also known as the "Bank Secrecy Act") required persons or institutions importing or exporting currency or other monetary instruments in amounts exceeding \$5,000, to file a Report of International Transportation of Currency or Monetary Instruments. These reports, commonly known as CMIRs, have been collected by the U.S. Customs Service since 1977. In 1980, the required reporting limit was raised to \$10,000. Although the CMIR data system was established with the aim of recording individual instances of cross border inflows and outflows of currency and monetary instruments, its micro data components can be usefully aggregated to study the size, origin, and destination of cross border currency flows. Since its inception, the CMIR data system has collected 2.3 million inbound filings and more than 300,000 outbound filings. With the cooperation of the U.S. Customs Service and the U.S. Treasury Department's Financial Crimes Enforcement Network (FinCEN), the information contained in the millions of accumulated confidential individual CMIR forms was combined by a specially designed algorithm that aggregated currency inflows and outflows by mode of transport and by origin and destination.

The CMIR data system represents the most comprehensive source of direct information on currency flows. It differs from the informal Federal Reserve data system (proxied by NYNET) in several important respects. It contains all reported currency inflows and outflows whether physically carried by individuals or shipped by financial institutions. The only excluded transactions are those that fall below the reporting requirements, direct shipments by Federal Reserve Banks, and shipments that circumvent the legal reporting requirements. The CMIR data are therefore more inclusive than the Federal Reserve informal series, which is limited to bank shipments to and from the New York Federal Reserve District by large bulk shippers.

Figure 11 displays the net outflows of U.S. currency as derived from the two direct sources of information pertaining to net outflows. The figure contains the NYNET proxy for the Federal Reserve informal series as well as the total net outflows as reported in the CMIR reports (CTNET). Figure 11 also displays two key components of the CMIR source data, namely the series of transported net outflows reported by financial institutions (CSNET) and the net outflows physically carried

by individuals (CCNET). The total net outflow series derived from the CMIR reports differs markedly from both the NYNET series and the net outflow series derived from indirect methods. In particular, CTNET suggests a significantly lower volume of net outflows than any of the other estimates. The source of the difference is largely due to the individual component (CCNET), which suggests that individuals physically transported larger amounts of currency into the United States than out of the United States for all periods except 1990. Since individual transactions are not recorded in the informal Federal Reserve data, it is necessary to examine more closely the conceptual relationship between CMIR direct source information on net outflows and the information on net outflows obtained by other direct and indirect means.

**Figure 11. Direct Estimates of Net Outflows  
NYNET and CMIR Annual Estimates**



*Conceptual and Empirical Comparisons  
of Direct Measures of Currency Flows*

Table 7 presents a conceptual comparison of the coverage of the CMIR reporting system and the Federal Reserve reporting system. The

table reveals that there are major differences in the conceptual content and coverage of the CMIR and FED currency flow data systems. In order to derive meaningful comparisons between the information content of the two reporting systems, it is first necessary to obtain measures of currency inflows and outflows that are conceptually comparable between the two data systems.<sup>19</sup> An algorithm was therefore written to aggregate the micro CMIR data records into currency flows that would be comparable to FED data in both content and coverage.

**Table 7. Content Comparison of CMIR and FED Currency Flow Reporting Systems**

Characteristics	CMIR	Federal Reserve
Level of aggregation	Individual transactions	Aggregate transactions of large bulk shippers
Number of records	2.3 million inflow records 300,000 outflow records	Approximately 62,000 records (7 years x 12 months x 8 banks x 93 countries)
Time periods	Monthly—1977-1994	Monthly—1988-1994
Private institutions	All reporting banks	Major New York banks
Federal Reserve banks	Not included	New York Federal Reserve
Individuals	Reported cross border currency transport $\geq$ \$5,000 (pre-1980); $\geq$ \$10,000 (1980-1994)	Not reported
Domestic coverage	Entire U.S. (all Federal Reserve Districts)	New York Federal Reserve Branch
Overseas coverage <sup>a</sup>	220 countries	93 countries

a. The countries reported in the two data systems do not match exactly. Differences reflect temporal name changes and different levels of country aggregation (i.e., United Kingdom vs. England and Scotland). A separate comparison algorithm was written which resolves these difficulties and creates two country sets: those included in both the Federal Reserve and CMIR data systems and those included in the CMIR system but not in the FED system.

Table 8 (A and B) presents an aggregation scheme for the CMIR data system that creates observations on particular currency inflows

**Table 8(A). CMIR-Currency Inflow Matrix: Notation**

Mode of transport	Shipped by bank			Carried by individual			Total CMIR
Destination district	Country of origin						
	FED countries	All other countries	Total shipped	FED countries	All other countries	Total carried	
NY district	CSINYF	CSINYO	CSINY	CCINYF	CCINYO	CCINY	CTINY
All other districts	CSIOF	CSIOO	CSIO	CCIOF	CCIOO	CCIO	CTIO
Total CMIR	CSIF	CSIO	CSI	CCIF	CCIO	CCI	CTI

**Table 8(B). CMIR-Currency Outflow Matrix: Notation**

Mode of transport	Shipped by bank			Carried by individual			Total CMIR		
District of origin	Destination country								
	FED countries	All other countries	Total shipped	FED countries	All other countries	Total carried			
	NY district	CSONYF	CSONYO	CSONY	CCONYF	CCONYO		CCONY	CTONY
	All other districts	CSoOF	CSOOO	CSO	CCOOF	CCOOO		CCOO	CTOO
Total CMIR	CSoF	CSOO	CSO	CCOF	CCOO	CCO	CTO		

and outflows that are conceptually comparable to the currency inflows and outflows believed to be captured in the Federal Reserve data system.<sup>20</sup> Individual CMIR currency inflow and outflow transaction reports are aggregated by mode of cross border transport and by the geographic origin and destination of the currency flow. Thus, for currency inflows, total CMIR inflows (*CTI*) were first disaggregated by mode of transport into transactions involving shipment by a financial institution (*CSI*) and transactions involving currency physically carried by individuals (*CCI*). Shipped inflows (*CSI*) were then further disaggregated by country of origin and Federal Reserve District of destination. It was then possible to recombine the shipped inflows into four exhaustive categories reflecting:

1. All shipments whose country of origin was contained in the FED data system and whose destination was the New York Federal Reserve District (CSINYF);
2. All shipments whose country of origin was not in the FED data system but whose destination was the New York Federal Reserve District (CSINYO);
3. All shipments whose country of origin was included in the FED data system but whose destination district was not New York (CSIOF); and
4. All shipments whose country or origin was not in the FED data system and whose district of destination was not New York (CSIOO).

Table 9 (A and B) presents the same inflow and outflow matrix for the FED data system, indicating that the only conceptually comparable currency flows captured by both data systems is CSINYF=FSI and CSONYF=FSO. None of the other flows captured by the CMIR data is available in the FED data. The Federal Reserve data system excludes currency shipments whose origin or destination are the eleven non-New York Federal Reserve Districts as well as shipments whose origin and destination are countries other than those appearing in the FED data system. The FED data also excludes all inflows and outflows of currency physically transported by individuals.

In order to gauge the empirical importance of the conceptual information content excluded from the FED data system, table 10 (A and B)

**Table 9(A). FED-Currency Inflow Matrix: Notation**

Mode of transport	Shipped by bank			Carried by individual			Total FED
Destination district	Country of origin						
	FED countries	All other countries	Total shipped	FED countries	All other countries	Total carried	
NY district	FSI	NA	NA	NA	NA	NA	NA
All other districts	NA	NA	NA	NA	NA	NA	NA
Total FED	NA	NA	NA	NA	NA	NA	NA

**Table 9(B). FED-Currency Outflow Matrix: Notation**

Mode of transport	Shipped by bank			Carried by individual			Total FED
District of origin	Destination country						
	FED countries	All other countries	Total shipped	FED countries	All other countries	Total carried	
NY district	FSO	NA	NA	NA	NA	NA	NA
All other districts	NA	NA	NA	NA	NA	NA	NA
Total FED	NA	NA	NA	NA	NA	NA	NA

**Table 10(A). CMIR-Currency Inflow Matrix: Percent of Total Currency Inflows (CTI) by Source**

Mode of transport	Shipped by bank			Carried by individual			Total CMIR
Destination district	Country of origin						
	FED countries	All other countries	Total shipped	FED countries	All other countries	Total carried	
NY district	50.9	0.5	51.5	3.8	0.5	4.2	55.7
All other districts	15.5	1.2	16.7	23.7	3.9	27.6	44.3
Total CMIR	66.4	1.7	68.2	27.4	4.4	31.8	100.0

**Table 10(B). CMIR-Currency Outflow Matrix: Percent of Total Currency Outflows (CTO) by Source**

Mode of transport	Shipped by bank			Carried by individual			Total CMIR
District of origin	Destination country						
	FED countries	All other countries	Total shipped	FED countries	All other countries	Total carried	
NY district	82.9	0.9	83.8	1.7	0.1	1.8	85.6
All other districts	4.4	1.8	6.2	5.2	2.9	8.1	14.4
Total CMIR	87.3	2.7	90.0	6.9	3.1	10.0	100.0

presents a percentage breakdown of the various disaggregated inflows and outflows contained in the CMIR data for the period 1988-1994 which corresponds to the time interval covered by the Federal Reserve statistics.

A major finding is immediately apparent from table 10 (A and B) concerning the relationship between Federal Reserve data as proxied by NYNET and CMIR data. Only 50.9 percent of all recorded CMIR inflows are likely to be captured by the FED data system, whereas 82.9 percent of all CMIR outflows are likely to be recorded by the FED data system. Since the CMIR data system includes many inflows of currency which are not represented in the FED data source, the FED net outflow series will overstate the net outflows of currency abroad and therefore give the misleading impression that a larger fraction of U.S. currency is held abroad.

Table 11 presents the means and standard deviations of various direct measures of average quarterly gross currency inflows and outflows. Comparing the means of the Federal Reserve and CMIR inflow and outflow estimates reveals that the CMIR data are considerably more inclusive than the Federal Reserve estimates.<sup>21</sup> Recorded average quarterly CMIR total currency inflows (CTI) exceed Federal Reserve (FSI) recorded bulk receipts of currency by some \$2.86 billion. Similarly, recorded average CMIR total currency (CTO) outflows exceed Federal Reserve (FSO) bulk currency shipments by \$1.39 billion per quarter. However, when conceptually comparable magnitudes are compared we find that CMIR estimates of bulk shipments to the New York Federal Reserve District from countries included in the FED data system (CSINYF) are, as expected, very close to the FED data (FSI). This is true to an even greater extent for comparable outflows.

Comparing conceptually comparable magnitudes reduces the inflow discrepancy to less than \$.2 billion (2,765-2,567) and the outflow discrepancy (6,015-5,869) to \$.15 billion. The average quarterly inflows of all commercially shipped currency (CSI) recorded by the CMIR data still exceed the Federal Reserve's estimated inflows (FSI) by roughly \$1.13 billion while the average CMIR shipped outflows (CSO) exceed the Federal Reserve's estimates of outflows (FSO) by \$.67 billion per quarter. These discrepancies are due to the fact that 16.7 percent of total CMIR currency shipped inflows arrive at banks outside the New York district, and 6.2 percent of CMIR outflows originate at banks outside of New York. The Federal Reserve's data appear to *understate* gross inflows to a greater degree than they understate gross outflows,



**Table 11(A). Descriptive Statistics of Direct Measures of Quarterly Gross Currency Inflows, 1988-1994**

\$ (Mil.)	CCI	CSI	CSINYF	CTI	FSI	NYIN
Mean	1,729	3,700	2,765	5,429	2,567	2,028
Std. Dev.	1,074	2,062	1,756	2,219	1,742	1,271

**Table 11(B). Descriptive Statistics of Direct Measures of Quarterly Gross Currency Outflows, 1988-1994**

\$ (Mil.)	CCO	CSO	CSONYF	CTO	FSO	NYOUT
Mean	724	6,535	6,015	7,259	5,869	6,265
Std. Dev.	583	2,473	2,532	2,539	3,250	3,045

leading to an *overstatement* of net shipped currency outflows. This is true to an even greater extent for the shipment proxy (NYNET). As displayed in table 10, individuals physically transport 31.9 percent of total gross inflows but only 10 percent of total gross outflows.<sup>22</sup> Since the FED data do not include currency physically transported by individuals, the overstatement of net outflows is further accentuated. Any conclusions derived from Federal Reserve data or from series closely correlated with FED data (such as NYNET), are therefore likely to overstate net outflows and therefore lead to the erroneous conclusion that foreign holdings of U.S. currency are increasing at a faster rate than is in fact the case.

This conclusion is subject to one caveat. It is likely that the CMIR filing compliance rate is higher for currency physically carried into the United States than for currency physically carried out of the United States, since U.S. Customs forms are routinely collected from incoming travelers. During the period 1988-94, there were roughly nine inflow filings for every one outflow filing, and the average size of reported outflows was almost four times larger than the average size of the corresponding reported inflow. The underreporting of physically transported outflows and their large average size would induce a downward bias to the carried currency component of CMIR net outflows.

In summary, the CMIR data represent the most comprehensive direct measure of currency inflows and outflows. We have shown that the one component of the CMIR data that can be directly compared with other direct data sources is very reliable. As displayed in table 12, the CMIR measure of net shipped New York outflows (CSNYFNET) is almost identical to the conceptually comparable figure (FSNET) yielded by the FED data system. The total CMIR quarterly net outflows (CTNET = CSNET + CCNET) are approximately \$.47 billion lower than the average of quarterly net outflows estimated from the note ratio models (PCE; PDI; POP,CPI) whereas the NYNET and SEANET estimates are approximately \$2.4 billion higher. The CMIR data's lower estimate of net outflows appears to be entirely due to the component (CCNET) representing physical transport of currency by individuals. This component is negatively correlated or uncorrelated with other net outflow measures. The individual component of the CMIR either reflects a unique information signal not contained in the other series or it may be the result of a compliance bias that differen-

**Table 12. Direct and Indirect Measures of Quarterly Net Currency Outflows, 1988-1994**

\$ (Mil.)	CCNET	CSNET	CTNET	CSNYFNET	PCE	PDI	POPCPI	NYNET	SEANET	FSNET
Mean	-1,005	2,835	1,830	3,250	2,391	1,839	2,661	4,237	4,201	3,303

tially effects the incoming and outgoing reporting of individual transport of currency.

### *Unrecorded Travel and Remittance Flows*

The only inflows and outflows not captured by the CMIR direct measures are those flows that fall below the reporting requirement and those flows that should legally be reported but escape detection due to noncompliance. If these flows are relatively large, and outflows substantially exceeded inflows, they could account for some of the observed disparities between the CMIR measure and other estimates of net outflows.

Three flows require further investigation. Unrecorded inflows include U.S. currency carried into the country by foreign travelers visiting the United States below the filing threshold; unrecorded outflows include U.S. currency taken abroad by U.S. travelers and net remittances of currency sent abroad. To estimate the size of these flows we examined annual data on total expenditures net of airfares made in the United States by foreign travelers to this country and total expenditures made by U.S. travelers abroad for the period 1962-1994.<sup>23</sup> To simulate the net outflows of currency deriving from travelers we assumed that prior to the widespread use of credit cards, foreign travelers to the U.S. made 20 percent of their purchases of goods and services with U.S. currency brought into the country from abroad, whereas U.S. travelers carried U.S. currency out of the country to cover 10 percent of their expected overseas expenditures. These proportions were reduced over time to allow for the growing use of credit cards. Net remittances are estimated by the Bureau of Economic Analysis, whose economists suggested that, at most, 10 percent of remittances involve transfers of U.S. currency. Our simulations over several sets of plausible assumptions revealed that annual net outflows of U.S. currency from travel and remittance sources rarely exceeded \$.5 billion and in most recent years, net outflows from these sources were actually negative. We conclude that the net currency flows arising from travel and remittance transactions that may be excluded from CMIR reports are too small to account for the disparities between CMIR net outflows and those estimated by indirect means. If anything, travel flow estimates tend to accentuate the observed discrepancies.

## Composite Estimates

Given the diversity of indicators of the unknown net flows of currency overseas, it is desirable to combine these alternative measures in order to obtain a single composite estimate of net currency outflows based on all available information. One approach is to use a factor analysis model to estimate the common signal or latent variable ( $L_t$ ) associated with several alternative indicators of net overseas currency flows ( $M_{it}$ ). In the factor model,

$$M_{it} = \beta_i L_t + \epsilon_{it},$$

each of the  $M_i$  indicators of net outflows is linearly related to the latent common factor ( $L_t$ ). The  $\beta_i$ 's represent the factor loadings and the  $\epsilon_{it}$  are the temporal measurement errors in each of the  $i$  measures of net currency outflows.<sup>24</sup> Since different estimates of net outflows are available for different time periods and different frequencies, we estimated several factor models for both annual and quarterly frequencies in order to examine the stability of the results. The variables employed and the periods covered by the various estimates are as follows:

### *Annual Factor Model 1 (AF1) - Period 1962-1994*

Six variables: Net outflows: MDM(S); NRM(PDI); NRM(PCE); NRM(POP,CPI); MDM(C/N); TRAV.<sup>25</sup>

### *Quarterly Factor Model 1 (QF1) - Period 1961:1 - 1994:4*

Four variables: Net outflows: NRM(PDI); NRM(PCE); NRM(POP,CPI); MDM(C/N).

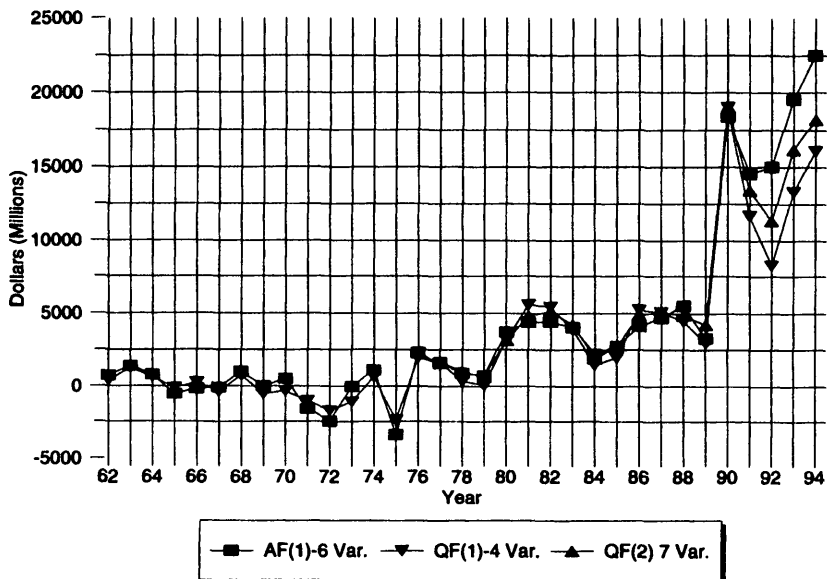
### *Quarterly Factor Model 2 (QF2) - Period 1977:1 - 1994:4*

Seven variables: Net Outflows: CCNET; CSNET; NYNET; NRM(PDI); NRM(PCE); NRM(POP,CPI); MDM(C/N).

Figure 12 displays the maximum likelihood estimates of annualized net outflows derived from each of the foregoing factor models. The temporal pattern of all the estimates is broadly similar, suggesting a rising level of net outflows during the decade of the 1980s and a significant upward shift in net outflows during the early 1990s, largely associated with the increased use of U.S. currency as a co-circulating

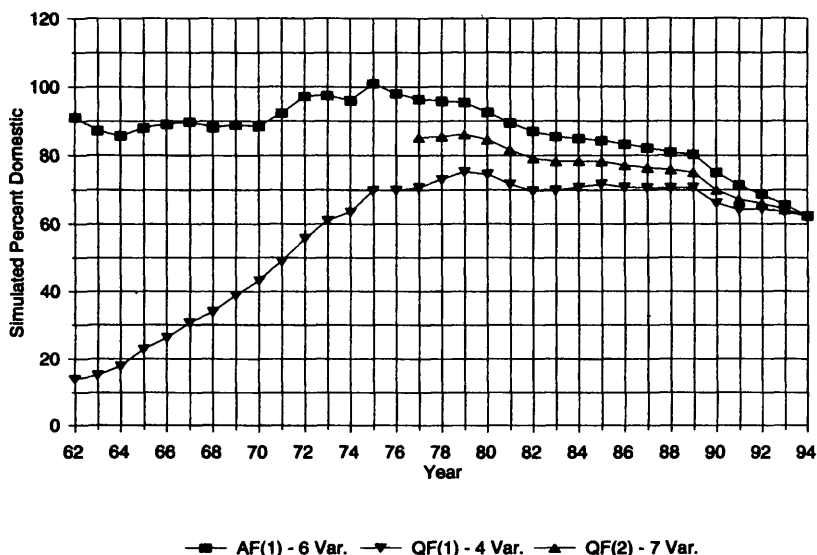
medium of exchange in Eastern Europe and the newly independent republics of the former Soviet Union. The annual model (AF1), incorporating MDM, NRM, and TRAV results produces the highest estimated net outflows during the most recent years, whereas the seven-variable quarterly model (QF2) employing direct (CMIR) and proxy estimates (NYNET) as well as MDM and NRM estimates produces the lower bound net outflow estimates. Given these alternative factor model net outflow estimates, it remains to determine what current share of overseas holdings is consistent with the net outflow evidence. To examine the plausibility of alternative assumptions concerning the current share of U.S. notes held abroad, we conducted a series of simulation experiments to determine the implied share of currency held domestically, given alternative assumptions concerning the present share of U.S. notes abroad.

**Figure 12. Estimated Factor Model Net Outflows  
1962-1994 Annual Net Outflows**



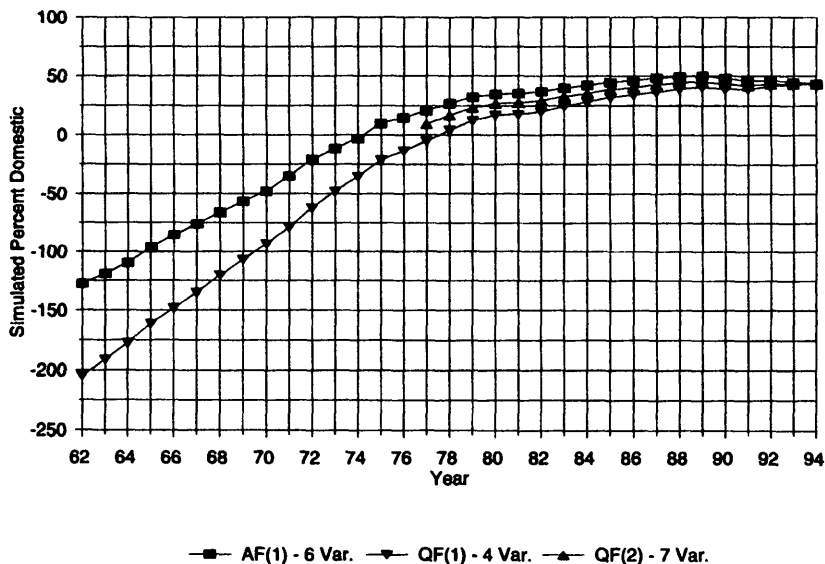
Figures 13 and 14, respectively, display the implied shares of currency held domestically over time assuming that the current share of notes held overseas is 40 percent and 60 percent. For the 40 percent Figures 13 and 14 respectively, display the implied shares of currency held domestically over time assuming that the current share of notes held overseas is 40 percent and 60 percent. For the 40 percent abroad simulation, all of the factor model estimates imply a feasible range of domestic holdings between 0 and 100 percent, whereas the 60 percent abroad simulations produce infeasible estimates which suggest that prior to the mid-1970s no U.S. currency was held domestically.<sup>26</sup>

**Figure 13. Domestic Share of U.S. Currency**  
Simulation: 1994=40% of Notes Overseas

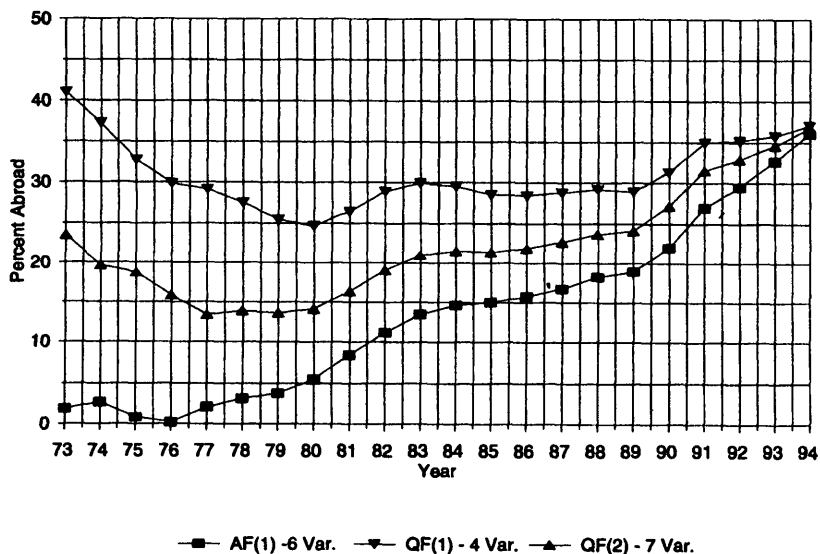


On the basis of the foregoing simulations, we conclude that the most plausible estimate of the share of U.S. notes presently held abroad is roughly 40 percent, which implies that roughly 36 percent of U.S. currency is held abroad.<sup>27</sup> Employing this current value, figure 15 displays the implied time series of the share of currency held overseas between 1973 and 1994 for each of the factor model net outflow estimates. Given the considerable range of overseas shares implied by the three factor model estimates, we conclude that precise estimates of the domestic money supply remain elusive.

**Figure 14. Domestic Share of U.S. Currency**  
**Simulation: 1994=60% of Notes Overseas**



**Figure 15. Foreign Holdings of U.S. Currency**  
**Percent of Currency Held Abroad**





### **Implications of Foreign Holdings of U.S. Currency for Estimates of the Domestic Unreported Economy**

The provisional estimates of overseas holdings suggest that earlier currency ratio model estimates of the unreported economy were mis-specified insofar as they erroneously assumed that the entire stock of U.S. currency was held domestically. It is now possible to reestimate the currency ratio models employing the new alternative estimates of the domestic stock of U.S. currency.

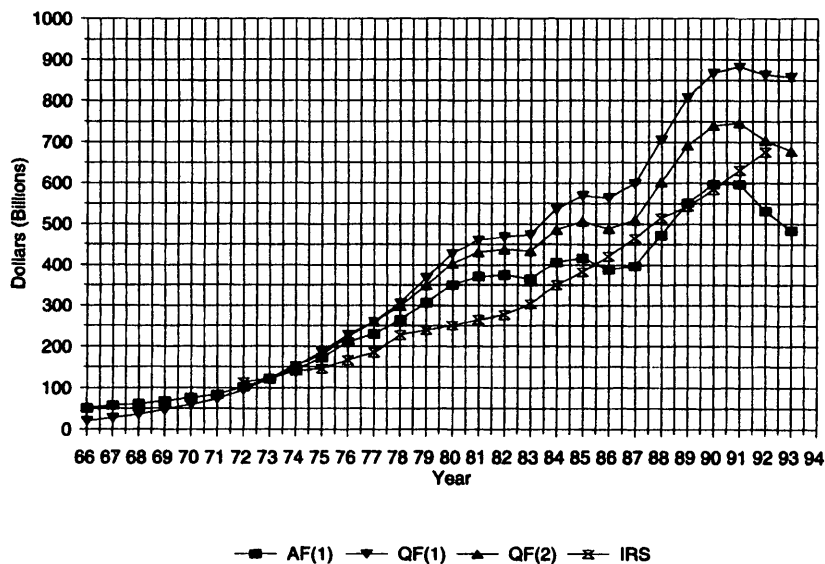
Figures 16 and 17 display estimates of total unreported income obtained from both the simple C/D model and the GCR model employing alternative factor model estimates of the domestic U.S. currency stock. Figure 18 displays the GCR estimates of unreported income as a percentage of AGI.

Total unreported income appears to have grown secularly until 1985, declined briefly around the time of the 1986 tax reform, and then peaked in 1991. The temporal pattern of the alternative GCR estimates of unreported income as a percent of AGI tells essentially the same story. Unreported income appears to have grown rapidly from 1966 and peaked as a percent of AGI in 1980. The percent of unreported income then declined until 1987, rose again until 1991, and fell again to a lower level approximating levels last observed in the early 1970s.

Of the three factor model estimates of the domestic currency supply, the QF2 estimate may be the most reliable, being based on quarterly frequencies and the largest amount of direct and indirect information concerning net currency outflows. The QF2 estimates from both the simple C/D and GCR models suggest that total unreported income in 1993 was roughly \$700 billion, representing approximately 20 percent of AGI.

The main conclusion to be drawn from these revised estimates of unreported activity is that once account is taken of foreign holdings of U.S. currency, the range of uncertainty concerning the magnitude of unreported income is substantially reduced. The difference between the unadjusted GCR estimates of unreported income and the IRS estimates for 1992 (figure 7) amounted to more than \$400 billion. The revised estimates displayed in figure 17 reveal that the difference between the IRS estimate and the QF2 estimate is now reduced to roughly \$100 billion.

**Figure 16. Total Unreported Income  
Adjusted C/D Models: 1973=IRS Base**



**Figure 17. Total Unreported Income  
Adjusted GCR Models: 1973=IRS Base**

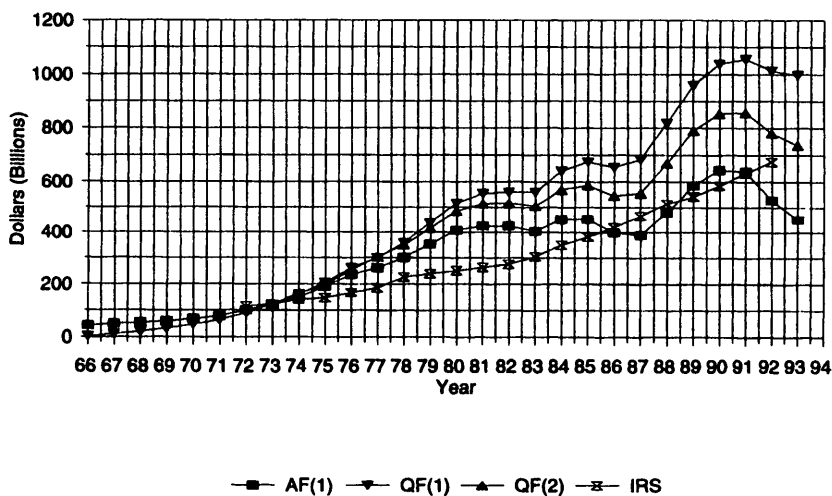


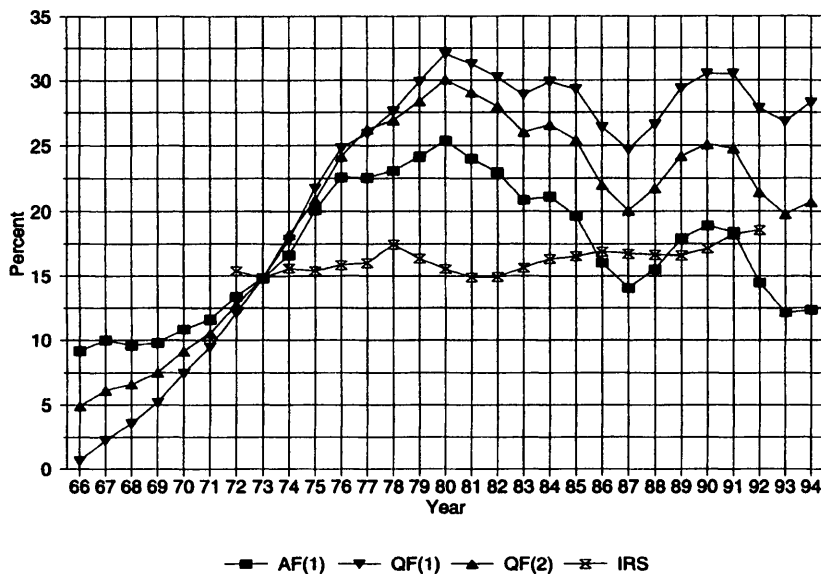
Figure 18 reveals that unreported income as a percent of AGI varies considerably over time. Whereas earlier studies of the underground economy reported its secular growth in both absolute and relative terms, the most recent data suggest that since 1980, unreported income as a percent of AGI has fluctuated quite dramatically. The two most plausible explanations of these fluctuations in unreported income are changes in average tax rates and changes in the level of dissatisfaction with government.

Figure 19 displays the relationship between the QF2 revised estimates of unreported income as a percent of AGI to the average effective federal tax rate, and figure 20 displays the relationship between unreported income and an index of dissatisfaction with government.<sup>28</sup>

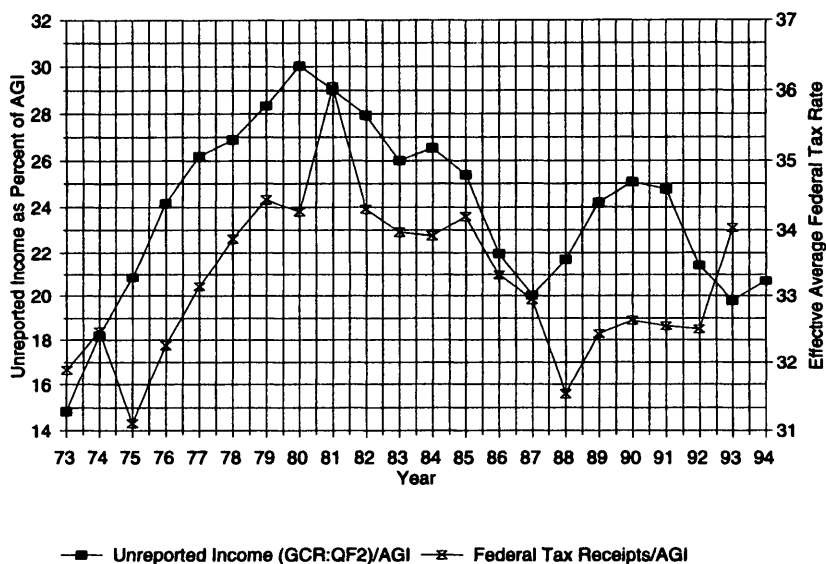
Figure 19 reveals that tax evasion does appear to rise in response to higher average taxes, and conversely falls when the incentives to cheat are reduced by lower average tax rates. Similarly, in figure 20 we find the expected relationship between tax evasion activity and the level of dissatisfaction with government. The dramatic fall in the level of dissatisfaction with the government between 1980 and 1984, coincides with a fall in the relative level of tax evasion. Conversely, the increases in the level of dissatisfaction with government observed between the mid-1980s and 1990 are associated with a relative increase in tax evasion activities. It seems that when taxpayers perceive their public representatives to be dishonest, and when they perceive a decline in the public benefits obtained from their tax dollars, they are more likely to engage in tax evasion.

The finding that a substantial portion of U.S. currency is held overseas provides a partial resolution of the currency enigma. It will be recalled that Federal Reserve surveys suggest that U.S. households admit to holding roughly 12 percent of the nation's currency, firms account for roughly 3 percent, the unreported economy employs roughly 4 percent, and foreign holdings amount to roughly 36 percent. These estimates suggest that we have accounted for 55 percent of the nation's currency supply, leaving 45 percent still to be explained. Porter and Judson (1995), who place considerable emphasis on their version of the MDM(S) and MDM(SR) results, suggest that a much larger fraction of U.S. currency is held abroad—between 50 percent and 70 percent. Our analysis suggests that these estimates of overseas hold-

**Figure 18. Unreported Income as a Percent of AGI  
Adjusted GCR Models: 1973=IRS Base**



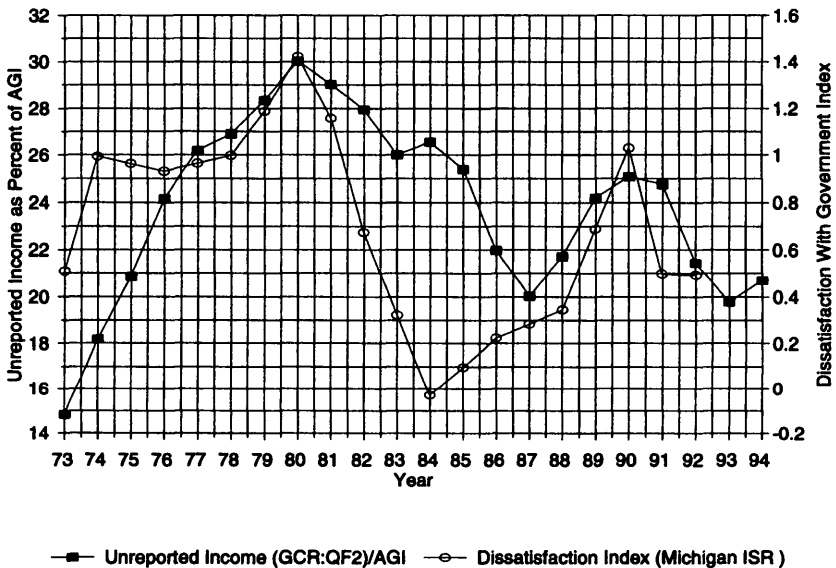
**Figure 19. Unreported Income and Tax Rate  
1973-1994**



ings are too high. We are more inclined to believe that survey respondents may systematically underreport the amounts of currency they hold and that surveys of currency usage may understate actual domestic holdings because of self-selection biases. Whether these domestic cash hoards are derived from underground activities that we continue to underestimate, or from legitimate activities that are simply underrecorded in our NIPA accounts, remains to be resolved.

The finding that roughly 36 percent of the stock of U.S. currency is currently overseas raises another monetary puzzle. Are foreign holdings of U.S. currency being used solely as a store of value or do they function as a co-circulating medium of exchange? Preliminary evidence (Feige 1994) based on an investigation of the age and quality of

**Figure 20. Unreported Income and Dissatisfaction  
1973-1994**



some 200,000 individual notes suggests that the age/quality distributions of domestically circulating notes and notes returning to the United States from abroad are quite similar. These findings suggest that the velocity of domestically held currency is on average not that differ-

ent from the velocity of currency held abroad. If foreigners' holdings of U.S. currency circulate at the same rate as that of U.S. household holdings, they would generate a flow of annual cash payments approaching the size of the GDP of the United States. Thus, the partial resolution of the currency enigma for the United States merely creates another monetary anomaly for the rest of the world. The world economy appears to subsume a U.S.-sized unrecorded economy that employs U.S. currency as its medium of exchange. The world's currency enigma deepens when one considers that our revised estimates of U.S. per capita currency holdings are still modest compared with the per capita currency holdings of other developed European and Asian nations. The problem of missing currency is not limited to the U.S. dollar but also extends to other major currencies, most importantly to the German mark and the Japanese yen.

## NOTES

1. Currency in circulation refers to the amount of currency held outside of the Treasury and Federal Reserve. Except for small amounts of currency that may have been inadvertently lost or destroyed by the public (Laurent 1974), currency in circulation includes the holdings of financial intermediaries and the public. Reliable data on financial intermediary holdings of vault cash are readily available, and it is therefore possible to obtain accurate estimates of the total stock of currency outside the banking system. For a complete description of the cash payments system, see Feige (1994).

2. The taxonomy of "underground economies," which identifies the interrelationships between the illegal, unreported, unrecorded, and informal economies, is discussed in Feige (1989, 1990a).

3. On page A-101 of the IRS (1988) report, the IRS acknowledges the major limitations of its projections of unreported income: "Because we essentially hold constant rates of noncompliance through 1992, these estimates do not reflect recent trends in noncompliance. Second, we assume that tax reform has no impact on individual's behavior in terms of either their propensity for noncompliance or the types of incomes individuals will receive in future years. Third, these projections are sensitive to changes in macroeconomic model projections of incomes in future years."

4. The IRS estimates reported above are based on the recommendations of the tax examiners. Since some of these recommendations are challenged by the taxpayer, the IRS also prepared an alternative set of estimates on an assessed basis. These are reported in Appendix E (IRS 1988).

5. As described in Feige (1989), the foregoing restrictions imply that the ratio of unreported ( $Y_u$ ) to reported ( $Y_o$ ) income can be estimated as follows:

$$Y_u/Y_o = (C - koD)/(ko+1)D$$

where:

$C$  = Currency

$D$  = Checkable Deposits

$ko = C_o/D_o$ .

6. The general currency ratio model (GCR) permits a relaxation of several of the assumptions employed in the simple currency ratio model. In particular, currency needs no longer to be the exclusive medium of exchange in unreported transactions, and any year for which an independent estimate of unreported income is available can serve as a benchmark.

The GCR model can be solved to obtain the equation for the ratio of unreported income which is:

$$Y_u/Y_o = (ku+1)(C-koD)/(ko+1)(kuD-C)$$

where:

$ku$  and  $ko$  respectively represent the currency-deposit ratios in the unreported and in the reported economies.

7. The IRS estimate is the sum of the legal source unreported income estimate displayed in figure 3 plus a 15 percent imputation for illegal source income. The imputation for illegal source income is based on the illegal source income estimates reported in the earlier (IRS 1983) study. The currency ratio models yield estimates of total unreported income from all sources.

8. The methodology for estimating the velocity (turnover) of currency is described in Feige (1990b). The estimates are based on the Federal Reserve's Survey of Currency Usage, which finds that the income velocity of household cash holdings is roughly fifty turnovers per year. Share weighted denomination-specific velocities are obtained by estimating the average lifetime of each note denomination derived from FR-160 data on currency issues (births) and redemptions (deaths).

9. The research reported here is one of several approaches undertaken as part of a broader study for the Board of Governors of the Federal Reserve System and the U.S. Treasury Department Financial Crimes Enforcement Network (FinCEN) on estimating foreign holdings of U.S. currency.

10. The application of demographic theory and methods to currency populations is developed in Feige (1990b), which includes estimates of age-specific currency mortality and survival rates. Feige (1994) presents a full demographic model describing the life cycle of the individual note and the dynamics of note populations and cohorts.

11. See the 1990 Federal Reserve Soil Level Impact Task Force (SLITF) study entitled "Comprehensive Assessment of U.S. Currency Quality, Age & Cost Relationships."

12. The estimates presented for denominations \$1, \$5, \$50, \$100 are averages obtained from Baselines 1 and 2 of the SLITF study. The Baseline 1 model for the \$10 denomination and the Baseline 2 estimates for the \$20 denomination failed to converge even after significant outliers were deleted from the samples. We therefore report a range of estimates for these two denominations. The similarity of the age distributions of overseas and domestic notes suggests that the reported results are likely to contain a wide margin of error.

13. The assumption is justified by the argument that the U.S. and Canada have identical currency denomination structures and that the Canadian dollar is rarely used overseas.

14. Porter and Judson claim that almost all currency sent to and received from abroad is processed by the New York Federal Reserve Bank. The veracity of this assumption can be tested by an examination of CMIR data disaggregated by Federal Reserve District of origin and destination. The CMIR data reveal that only 52 percent of all reported currency inflows for the period 1977 and 1994 had the New York Federal Reserve District as their point of destination. The New York District was reported as the point of origin for 85 percent of total outflows during the period.

15. The reported results include an adjustment of the coin/note ratio to take account of the introduction of a one dollar coin in Canada in July 1987. The Bank of Canada continued to issue one dollar notes until June 30, 1989, at which time there were 246 million of the one dollar coins in circulation. By the end of 1989, the number of one dollar coins in circulation had risen to 464

million. The reported results are based on a time series forecast of what the coin/note ratio would have been in the absence of the introduction of the one dollar coin.

16. Porter and Judson obtained the seasonal components employing the STL seasonal adjustment procedure applied to the currency component (coin plus notes) of the Canadian and U.S. M1 series. In our replication, we employed the X11 ARIMA procedure on the Canadian and U.S. notes in circulation series, since neither Canadian nor U.S. coins are assumed to circulate overseas. The results reported by Porter and Judson are not based on the ratio of seasonal components as specified by Equation (6), but rather on the ratio of the seasonal amplitudes of the U.S. and Canadian series, derived by taking the difference between the December and February seasonals (Porter and Judson 1995, pp. 16-17). Our replication efforts suggest that the results are relatively insensitive to the use of different seasonal adjustment procedures and the substitution of the note series for the currency component series. However, the time series estimates of the share abroad are quite sensitive to the use of the seasonal amplitude metric employed by Porter and Judson. In particular, when the MDM(S) model is estimated on a monthly or quarterly basis, and the estimated monthly or quarterly overseas share is estimated as the ratio of each of the seasonal components minus one as suggested by Equation (6), the estimated monthly and quarterly shares abroad fluctuate wildly within a year, often yielding estimates of the share abroad that exceed 100 percent.

17. Throughout the analysis we assume that all U.S. coin is held domestically.

18. During the inter-war period between 1923 and 1941, the Federal Reserve published data on net currency shipments to European countries (Banking and Monetary Statistics: 1914-1941, Board of Governors of the Federal Reserve System, 1943, pp. 417-418). Over the entire period for which data are available, cumulative net inflows from Europe amounted to 4.8 percent of the average outstanding stock of currency during the period. The average annual net inflow of currency from Europe amounted to .25 percent of the average outstanding currency stock.

19. In order to maintain strict confidentiality of individual records in the CMIR data system, aggregations were performed at the offices of the U.S. Treasury (FINCEN). Subsequent analysis was performed on the aggregated data. Since Federal Reserve Banks are not required by law to file CMIR statements, the CMIR shipment series were augmented to include direct overseas currency shipments to and by the Federal Reserve Bank of New York.

20. The remaining minor incompatibility derives from the fact that CMIR records were created by Federal Reserve District whereas the FED data includes only observations for the New York Federal Reserve Branch of the New York Federal Reserve District. CMIR observations for the New York District therefore include the negligible transactions of the Buffalo Branch.

21. Under current CMIR reporting requirements, direct Federal Reserve Bank overseas currency shipments are not reportable on CMIRs but are included in the FED shipment series. In order to make both series comparable, direct Federal Reserve Bank shipments were added to the CMIR shipment series.

22. The series on individual inflows and outflows appear to be very different from the bulk shipments undertaken by financial institutions. Two explanations are possible for this important disparity. The data on physical transport by individuals include travel transport companies such as airlines or cruise ships that may generate U.S. currency outside the United States and regularly transport it back for deposit in their domestic bank. The discrepancy may also be due to differential rates of compliance with CMIR reporting. Individuals transporting currency out of the country are not monitored as carefully by the U.S. Customs as individuals returning to the United States. It is therefore possible that there is a lower rate of reporting compliance with physically transported outflows than with physically transported inflows.

23. The data were generously provided by the United States Travel and Tourism Administration, Washington, D.C.



24. A general discussion of factor analysis models can be found in Mulaik (1972). Bollen (1989) contains a review of factor analysis in the context of latent variables.

25. TRAV is an annual estimate of the net outflow of U.S. currency resulting from travel to and from the U.S. and net cash remittances sent abroad.

26. It should be noted that the individual net outflow results are even more sensitive to initial starting overseas values. In particular, the MDM(S) net outflow results only produce feasible estimates if we assume that between 65 and 75 percent of currency is presently overseas, whereas at the other extreme, the CMIR net outflows only produce feasible estimates in the 15 to 25 percent range.

27. Throughout the analysis, we assume that all U.S. coin is held domestically.

28. The average effective federal tax rate is simply the sum of federal government tax receipts divided by AGI. The dissatisfaction with government index is constructed as an equally weighted average of three normalized indices representing answers to the University of Michigan's Institute for Social Research (ISR) surveys concerning whether government officials can be trusted, whether they are crooked, and whether the government wastes taxpayers' money. I am indebted to the ISR for providing the underlying data.

## References

- Abt Associates. 1984. "Unreported Taxable Income From Selected Illegal Activities." Government Printing Office, September.
- Anderson, P. 1977. "Currency in Use and in Hoards," *New England Economic Review* (March/April): 21-30.
- Avery, R.B., G.E. Elliehausen, A.B. Kennickell, and P.A. Spindt. 1986. "The Use of Cash and Transaction Accounts by American Families," *Federal Reserve Bulletin* 72 (February): 87-108.
- \_\_\_\_\_. 1987. "Changes in the Use of Transaction Accounts and Cash from 1984 to 1986," *Federal Reserve Bulletin* 73 (March): 179-196.
- Cagan, P. 1958. "The Demand for Currency Relative to Total Money Supply," *Journal of Political Economy* 66 (August): 303-328.
- Carson, C. 1984. "The Underground Economy: An Introduction," *Survey of Current Business* 64, 5 (May and July).
- Federal Reserve System. 1990. *A Comprehensive Assessment of the U.S. Currency System: Quality, Age and Cost Relationships*. Federal Reserve System.
- Feige, E.L., ed. 1989. *The Underground Economies: Tax Evasion and Information Distortion*. New York: Cambridge University Press.
- \_\_\_\_\_. 1990a. "Defining and Estimating Underground and Informal Economies: The New Institutional Economics Approach," *World Development* 18, 7 (July): 989-1002.
- \_\_\_\_\_. 1990b. "Currency Velocity and Cash Payments in the U.S. Economy: The Currency Enigma." Mimeo, Department of Economics, University of Wisconsin.
- \_\_\_\_\_. 1994a. "The Underground Economy and the Currency Enigma," *Public Finance and Irregular Activity*, supplement to *Public Finance/Finances Publiques*, 49: pp. 119-136.
- \_\_\_\_\_. 1994. "The Cash Payment System: Monetary Demography." Report prepared for the Board of Governors of the Federal Reserve System and the Financial Crimes Enforcement Network.
- Gutmann, P. 1977. "The Subterranean Economy," *Financial Analysts* 33 (November/December): 24-27.
- Internal Revenue Service (IRS). 1979. "Estimates of Income Unreported on Individual Tax Returns." Department of the Treasury Publication No. 1104 (9-79).
- \_\_\_\_\_. 1981. "Study of the Information Returns Program." Department of the Treasury, Research and Operations Analysis Division, July.

- \_\_\_\_\_. 1983. "Income Tax Compliance Research." Department of the Treasury, July.
- \_\_\_\_\_. 1988. "Income Tax Compliance Research." Supporting Appendices to Publication 7285, Department of the Treasury, Research Division Publication 1414 (7-88).
- \_\_\_\_\_. 1990. "Income Tax Compliance Research: Net Tax Gap and Remittance Gap Estimates." Department of the Treasury, Research Division Publication 1415 (4-90).
- Laurent, Robert. 1974. "Currency in Circulation and the Real Value of Notes," *Journal of Money, Credit and Banking* 6, 2 (May): 213-226.
- Muliak, S.A. 1972. *The Foundations of Factor Analysis*. New York: McGraw-Hill.
- Office of National Drug Control Policy. 1991. "What American Users Spend on Illegal Drugs." Technical Paper, June.
- Porter, R. 1993. Appendix to "Nominal Income Targeting with the Monetary Base as Instrument: An Evaluation of McCallum's Rule." Federal Reserve Board Finance and Economics Discussion Series, Working Study No. 1.
- Porter, Richard D., and Ruth A. Judson. 1995. "The Location of U.S. Currency: How Much Is Abroad?" Reproduced by Board of Governors, Federal Reserve System.
- Sprenkle, C. 1993. "The Case of the Missing Currency," *Journal of Economic Perspectives* 7, 4 (fall): 175-84.
- Sumner, Scott B. 1990. "The Transactions and Hoarding Demand for Currency," *Quarterly Review of Economics and Business* 30, 1 (spring): 75-89.